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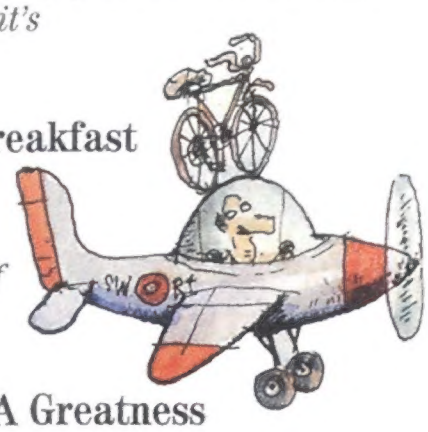

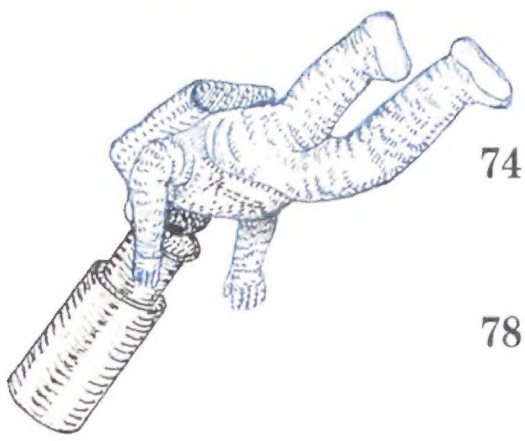

Cover:
Delmar Benjamin pilots his Gee Bee R-2 replica over the Arizona-Utah border in this photograph by Michael Haberlin.

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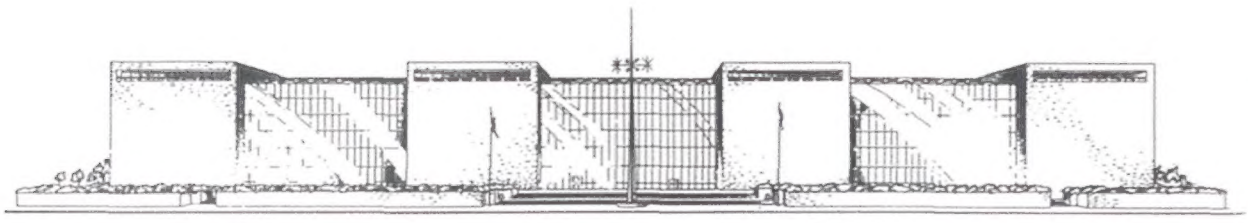

Big Science

Experience with initiating big science projects shows that we do not always succeed in having scientists, engineers, managers, and politicians work together effectively. Thus we are opting for "faster, better, cheaper" projects. This is prudent where germane, but it eliminates many space ventures that are inherently large or complex.

Big science doesn't necessarily imply large machines, though sometimes it does. The now-aborted superconducting supercollider involved a cavernous 54-mile-long underground doughnut in rural Texas. But other big science projects requiring comparable investments use small equipment, as in the design of next-generation gigabyte memory chips or the decryption of the human genome.

Is big science then just big spending? Only partly. We could spend just as much money on myriad small projects—and often used to. But the real defining character of big science is the investment of huge resources in a single goal.

The archetypal big science project has a unique mission whose realization requires a sizable army of specialists hand-picked from widely dispersed disciplines. That army must be paid, which is one reason why big science is expensive. But the main reason the costs are so high is that such projects are unique. For that reason, they tend to require new methodologies that must be researched, tested, and refined.

For a big science initiative to succeed, the wealth of assembled talent and expertise must be fashioned into a coordinated team. This is a major challenge, requiring the conscription, usually for a limited number of years, of specialists from different areas who have never worked together before and often bring to the project diametrically opposed professional and managerial philosophies and backgrounds.

Few individuals participate in the inception of more than one such venture in the course of a career. The life span of big science projects and their great expense preclude more than one or two new starts within a given discipline in a professional lifetime. This makes virtually everyone starting a big science project a newcomer, and just about invites managerial chaos—at least in terms of current management practice.

Where, for starters, can one find a leader to run a big science project? Understanding the science of the project is a clear advantage. But only rarely does one find a J. Robert Oppenheimer, with broad insight, able to understand at least a large fraction of the specialized problems that will have to be overcome. And the best scientists tend to be independent of mind. Team efforts are rarely their forte.

Alternatively, one might look for leadership among systems engineers with a talent for taking an array of laboratory science components and making them mutually compatible and sufficiently rugged and reliable to assure flawless operation with little down-time. Or one could pick a professional manager with a knack for organizing an army of individualists into a team dedicated to reaching its goals on schedule and within budget.

But throw in the politics of justifying continuity of funding, year after year, on a typically decade-long project, and you are asking for Wernher von Braun-caliber leadership. From time to time such a talented leader emerges; unfortunately, however, it's not something that we can count on.

Big science in space is here to stay, but we must learn to master it. To become effective, we must fathom its inherent challenges, and train a generation of scientist-engineer-manager-politicians to run such projects effectively. We have always educated scientists, engineers, and managers in different schools, as though they were to work in entirely different worlds. In big science, this separation is detrimental and we need to find better ways of organizing our efforts.

—Martin Harwit is the director of the National Air and Space Museum.

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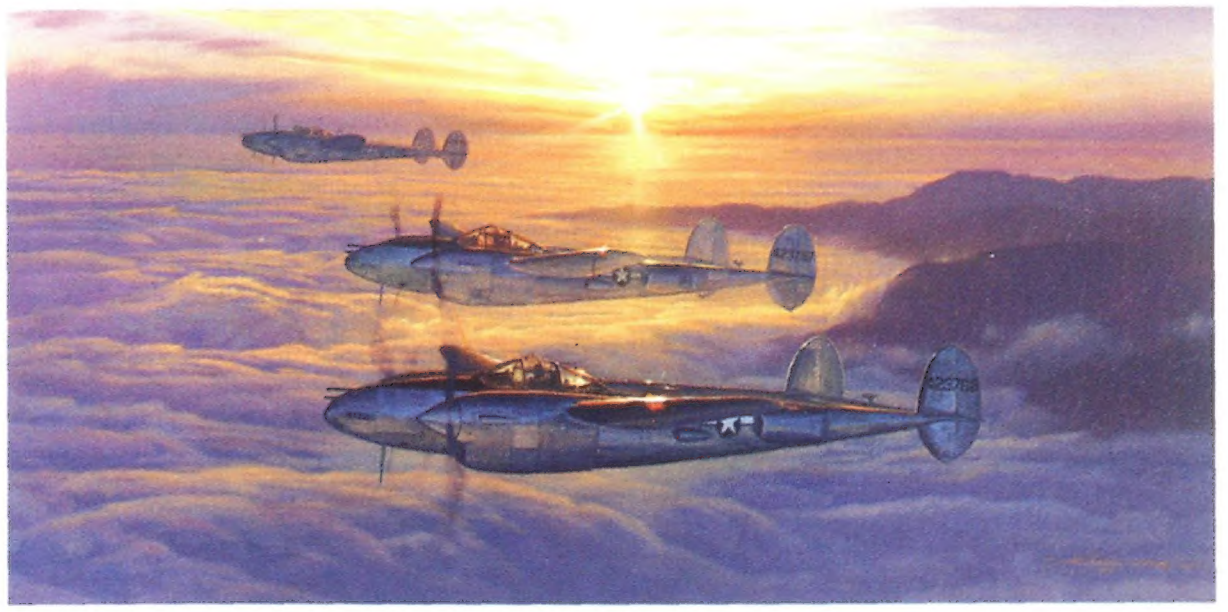

A.M. Sortie

by Craig Kodera

The Lockheed P-38 Lightning, known as *Der Gabelschwanz Teufel* (The Fork-Tailed Devil) by the German Luftwaffe, won the 1937 U.S. Army Air Corps design competition for a high-performance pursuit plane. Here the last three "F" models to be produced fly near the Lockheed factory in Burbank, California, during the summer of 1944.

Last to Fight

by Craig Kodera

15-16 August 1945: Lady in the Dark, a P-61 Black Widow from the 548th Night Fighter Squadron flown by Distinguished Flying Cross recipient Lee Kendall, embarks on its final mission of the Second World War. In capping the crash of a Japanese Ki-44 Shoki ("Tojo") on that mission, Lady in the Dark became the last American aircraft to be engaged in World War II aerial combat.

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LETTERS

It's Our Topic Too

Having grown weary of those who seem to feel that the topic of aerospace should be the exclusive domain of right-wing cranks, veterans, and firearms enthusiasts, I would like to respond to the comments of J. Don Marioni and John L. Berger, which appeared in last issue's Letters section under the headline "Is *Air & Space* PC?"

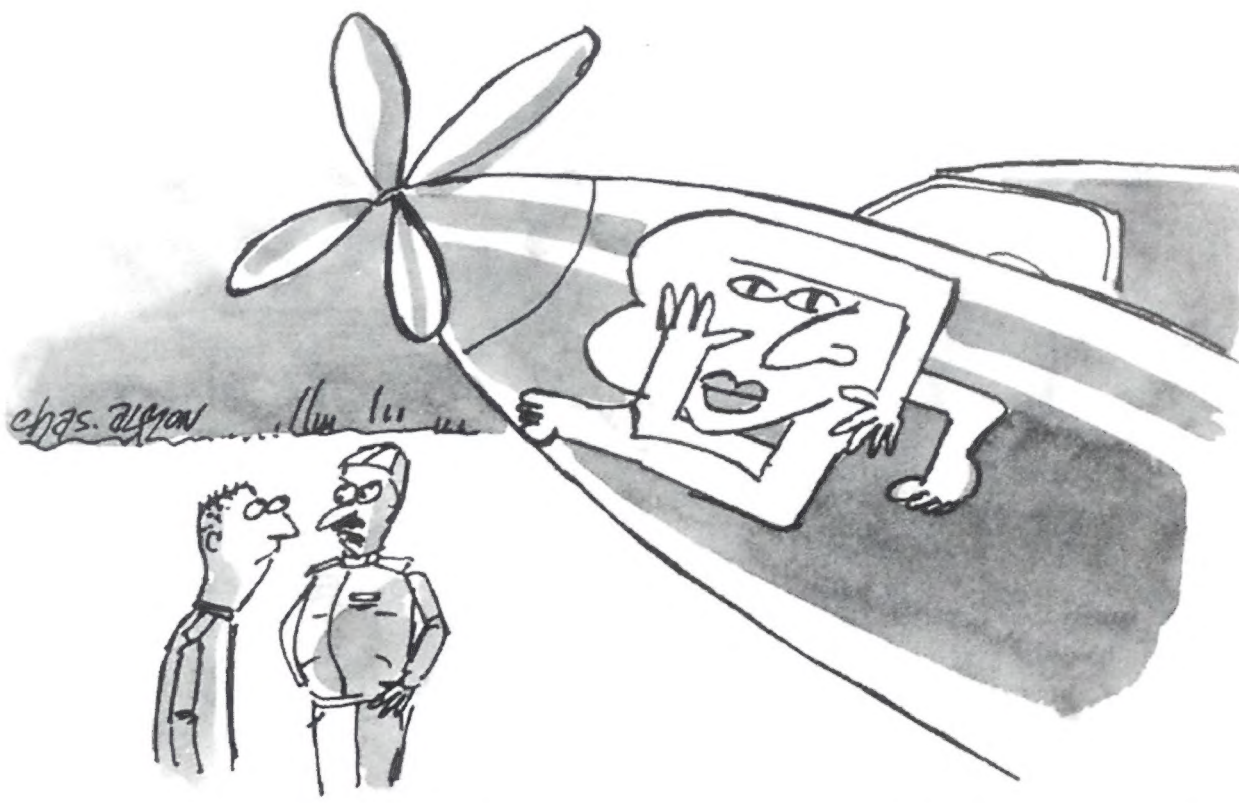
First, I found Marioni's assertion that black aviator Bessie Coleman "made no contribution to the field" debatable. Coleman's career, and your coverage of it ("My Quest for Queen Bess," Aug./Sept. 1994), could open the eyes of some people, regardless of race or gender, to the beauty of aviation and the opportunities therein for those not traditionally identified with the field. I think that is a valid contribution.

As to John L. Berger's complaint that you printed a "crock...environmentalist article" ("Ozone Forecast: Partly Cloudy," Oct./Nov. 1994), I can guarantee that if he found your tame and even-handed article to be "environmentalist," he's never read anything written by a *real* environmental activist.

As an unabashed liberal, I get sniped at by both sides for my love of aircraft, especially military planes. Friends on the left tend to see it as a childish fascination with things of a war-like, imperialistic nature. Those on the right act like it's "their" subject and none of my damned business.

I have been reading your magazine cover to cover for about six months now, and I enjoy it. My only complaint is that you tend to pander just a shade much to the aforementioned cranks, veterans, and gun folks. I hope you and your readers remember that you are a publication of the Smithsonian, which was established for the enjoyment and edification of all our citizens. There are a lot of us out here who are essentially pacifists but fully appreciate the need for top-notch military technology and a credible deterrent, who support social programs *and* an aggressive space program, and who simply love airplanes.

—Patrick Lubow
Alhambra, California



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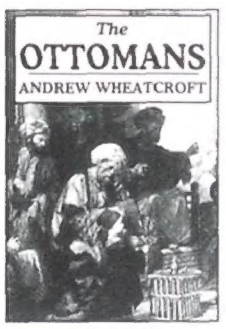

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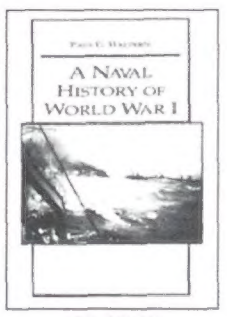

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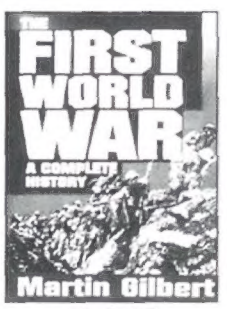

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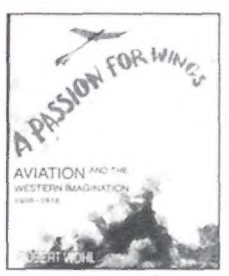

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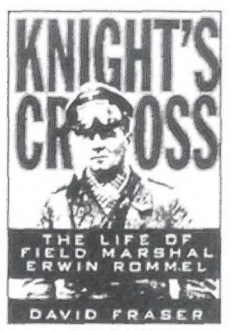

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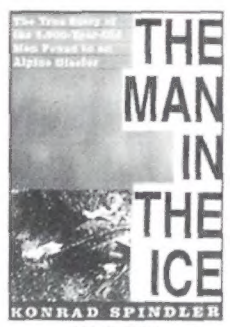

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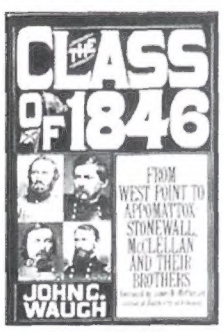

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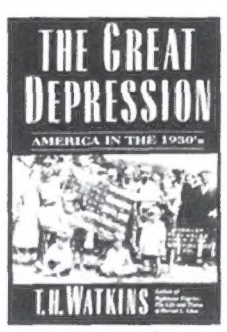

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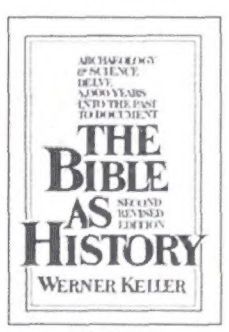

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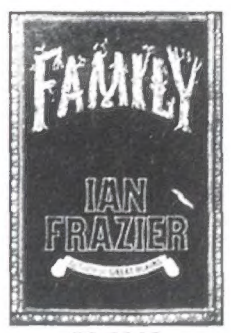

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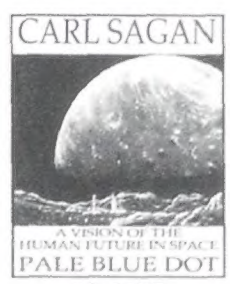

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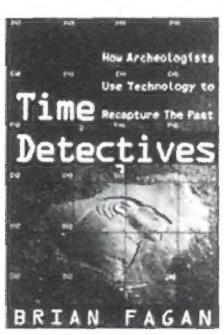

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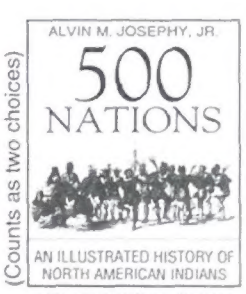

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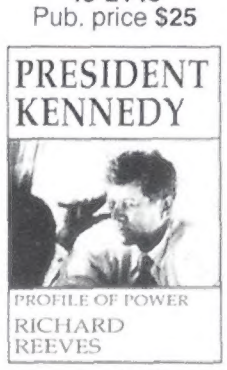

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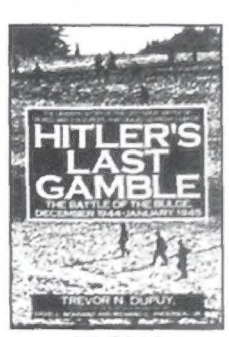

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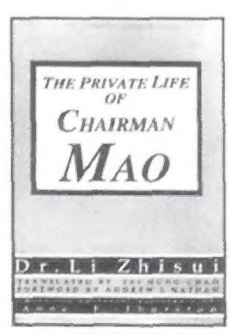

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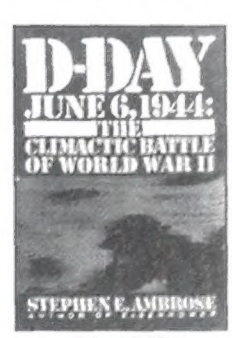

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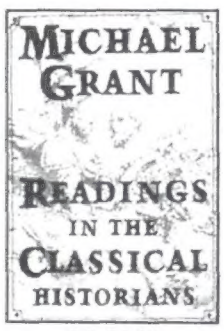

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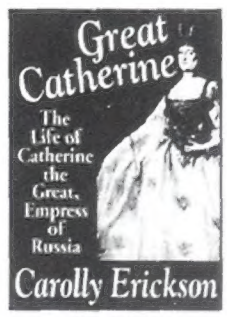

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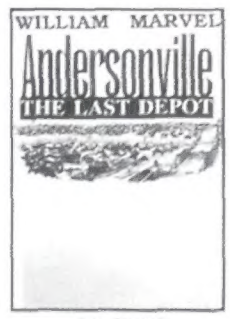

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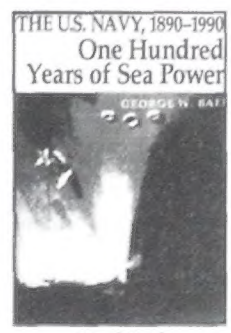

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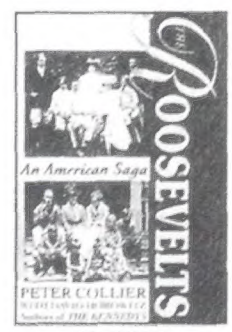

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"I'm afraid it's gingivitis."

The Trouble With Russia

"The Unfriendly Skies" (Aug./Sept. 1994) was not an altogether bad article, but it falls far short of a balanced and informed piece of journalism. It appears to be written by someone who made a couple of flights on Aeroflot and immediately became an authority, partly by quoting from more experienced writers, such as myself.

After Bill Thomas called me to discuss Aeroflot's historical role, he reported only my negative comments and omitted all the positive ones. I have taken 30 to 40 Aeroflot flights, from Ilyushin Il-86 wide-bodies to Antonov An-2 *kukuruzhnik*s, and in my experience the airline consistently meets its schedules, with pilots "greasing them in," even on poor airfield surfaces out in the Siberian boondocks.

Thomas made several clear-cut errors. Aeroflot does not fly only to international destinations. It flies to almost every major city of Russia. The reference to "crashes [that] have become so common" was obviously written before the recent record of USAir was publicized. Still, no one can dispute the irresponsibility of the pilot who turned control of his A310 over to his teenage son, causing the craft to crash. And it is sad to contemplate that the reputations of tens of thousands of well-trained, disciplined, and conscientious Russian air crews have been stained by association. Incidentally, of the last five Aeroflot accidents, two aircraft were brought down by missiles in the Caucasus, one was the result of a pilot being forced to take off, thrice overloaded, with a pistol to his head, and a fourth was due to a design circumstance (it could hardly rate as a defect) that, after 15 years of flying by hundreds of the type, finally fell victim to Murphy's Law.

Thomas makes much of paying $147 to fly on Komi Avia from Moscow to Vorkuta. But this is a distance of 1,300 miles—the same as that between Washington, D.C., and Dallas, Texas. Not a bad deal.

Today, Aeroflot's services are comparable to those of many major international airlines. Bill Thomas' article does less than justice both to an airline striving to maintain high standards and to your magazine.

—Ron Davies
McLean, Virginia

[The writer is the National Air and Space Museum's curator of air transport.]

Bill Thomas replies: After taking some 20 trips on Aeroflot in the last five or six years, I think I qualify as one of the airline's frequent fliers. I have also lived in Russia and have written extensively about the country.

I too admire the skills of Russian pilots, but with the collapse of the Soviet Union, safety has declined to the point where some foreign governments, including, until recently, the U.S., advise travelers to avoid Russian airspace.

I'm as interested in balanced journalism as Mr. Davies is, so I'm surprised he failed to mention that he once wrote a glowing history of the Aeroflot "company" when it was a wholly owned subsidiary of the Soviet government. Judging by the popularity of Mr. Davies' book at Aeroflot headquarters, where the publicity department in Moscow distributes it free of charge, he has obviously earned the red-carpet treatment. Most Russians, on the other hand, are used to the airline treating them as little better than baggage, and have welcomed competition from service-oriented newcomers.

In regard to Komi Avia, I wasn't complaining that the airline was overpricing its fares to Vorkuta but rather that it charges foreigners twice as much as Russians.

Finally, I never at any time talked to Mr. Davies in connection with my story. I did quote from his book about the airline to make the point that Aeroflot, at least by official Communist standards, once "did its job superbly," flying everything and everybody from tractor parts to political prisoners to their appointed destinations. Now those are the good old days.

Inflammatory Statements

In "Tovarich!" (Dec. 1994/Jan. 1995) Caldwell Johnson is quoted as stating that oxygen is flammable. Actually, a substance is flammable if it reacts readily with oxygen, and oxygen does not react with itself. The oxygen in Apollo 1 *was* dangerously supportive of combustion. However, that was due not to its purity but to the fact that it was pure *and* pressurized to 16 pounds per square inch.

Yes, I am a retired chemist.

—M.T. Esterdahl
Indian Shores, Florida

Airing Differences on the Ozone

I read "Ozone Forecast:Partly Cloudy" (Oct./Nov. 1994) with great interest. The stratospheric ozone issue is, as Carl Posey asserts, "a complex cautionary tale." His final remark, that other environmental issues certainly will arise, could not be more true.

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Yet prior to these lucid comments, Mr. Posey is quite confused. Recently, over 200 meteorologists, physicists, engineers, and chemists from around the world reaffirmed the current knowledge about stratospheric ozone. (The fact that more than half of these scientists were physicists and meteorologists lays to waste one of Mr. Posey's main motifs: that there is a schism between chemists and meteorologists.)

The consensus statement of these scientists supports the need for the Montreal Protocol controlling human-made chlorine- and bromine-containing substances, and it resolves much of the confusion Posey creates. The scientists agree that the Antarctic ozone hole and the Arctic springtime loss are set up by meteorological conditions but are caused by chlorine and bromine reactive gases, most of which come from human-made compounds. The weight of evidence suggests that even global ozone decline is due, at least in part, to chlorine and bromine compounds.

These scientists agree that ultraviolet-B (UV-B) at Earth's surface increases when stratospheric ozone decreases for clear skies, as expected from theory. An expected long-term increase in UV-B at Earth's surface has not been observed because changes in cloudiness, pollution, and other factors not linked to stratospheric ozone obscure but do not negate clear-sky results. The new clear-sky results refute Mr. Posey's statement that the "original question [UV-B increase] remains almost as pristinely unanswered as it was in 1974."

Mr. Posey is unconcerned about increased UV-B. However, non-melanoma skin cancers are estimated to increase by hundreds of thousands per year, not the "few thousand" that Mr. Posey claims. And although the significance of all potential effects is still unknown, the large number of potential and demonstrated effects and the long recovery time of the atmosphere urge us to take prudent measures now.

Last December, at the invitation of the American Geophysical Union, I presented a public lecture at the Exploratorium in San Francisco. As a scientist whose research is supported by public funds, it is my duty, when called, to present to the public my understanding of stratospheric ozone decline. *That* was my primary motivation for this lecture, not seeking attention, as Mr. Posey says.

My hour-long lecture mainly concerned the link between ozone loss and human-made compounds; only a few minutes were devoted to potential effects of UV-B.

Mr. Posey evidently attended this lecture. He either did not understand me or did not agree with me. In any case, he distorts my thoughts and makes factual errors. I am not a chemist, as Mr. Posey supposes, but a physicist by training, a professor of meteorology, and well beyond "30-something."

Mr. Posey quotes me directly only twice. Generally he uses summaries, along with words like "intones" and "suggests," to report what I said. A litany of the resulting errors includes:

- "speaks ominously of a shattered oceanic food chain, of land plants stunted and withered by this invisible light, of a weakened human immune system..." (I briefly showed these potential problems and mentioned some of the conflicting studies.)
- "Stratospheric ozone...has never been in such short supply" (Total ozone is as low as any in the last 20 years, but no one knows about earlier times.)
- "To their right...are the fringe media...the Larouchers, the crazies, who think there is no ozone problem at all" (This is an invention of Mr. Posey. I don't even know how Larouchers feel about this issue, and I never use the word "crazies.")
- "One of the frightening scenarios invoked by William Brune...is the destruction of the underpinnings of the ocean food web." (Once again, I stated explicitly that all of the repercussions of enhanced UV-B were unknown.)
- Mr. Posey writes that I believe that this "revisionist science...is as reprehensible as the revisionist history that denies the truth of the Holocaust." This abomination is his distortion of my remark that revisionist science is being applied to the ozone issue, just as revisionist history is being applied to the Holocaust. My statement and his distortion have entirely different meanings.

Mr. Posey says often that I frightened the people in my audience. I looked into their faces; I answered their questions; I engaged in dialogue. Some were interested and I hope all were listening. However, I never sensed or heard any fright.

We have made tremendous strides along the path toward an understanding of the stratospheric ozone issue. Let's keep on the path.

—William H. Brune
Pennsylvania State University
State College, Pennsylvania

Carl Posey replies: I regret being taken in by Mr. Brune's sounding and behaving like a chemist, and for his having worn so well that I placed him in his 30s. I am otherwise comfortable with my "confusion," but offer the following clarifications.

He identified himself with the view prevailing among atmospheric chemists, indicated with a gesture to his right that there was a more conservative group of meteorologists who questioned that view, and with a further gesture evoking a fringe group to the right of them. The terms "Larouchers" and "crazies" were used by others I interviewed to describe that fringe.

Regarding the Holocaust analogy, Mr. Brune raised the idea, somewhat incoherently, that there was "a lot of discussion" that went against the orthodox

UNIDENTIFIED FLYING OBJECT

Can you identify this aircraft? From time to time the National Air and Space Museum receives photographs of objects that its archivists cannot identify. This image is part of a collection that shows U.S. Marine Corps aircraft, apparently photographed at Quantico, Virginia, around 1923 to 1925. The wings in the background belong to a Martin MBT torpedo bomber, but the identity of the biplane in the foreground is unknown. If you can identify this UFO, write to: Letters, Air & Space/Smithsonian, *901 D St. SW, 10th Floor, Washington, DC 20024. Please type or print clearly, and include your daytime phone number. The archivists would especially appreciate photocopies of supporting evidence.*

We received two promising leads on the Dec. 1994/Jan. 1995 UFO. David Layton proposed that the craft was an S.2, produced by Italy's Società Aeronautica Meccanica Lombarda (SAML), while John W. Kalusa thought it was a SAML-made Aviatik B-1. The archivists are pursuing both possibilities.

Roland L. Scharping identified the Oct./Nov. 1994 UFO as the Dunham "Coupe" Monoplane, which Erwin J. Dunham of Hamburg, New York, completed in 1927.

view of ozone depletion—"like the Holocaust," he said. He clearly did not mean to equate ozone depletion and the Holocaust, but he seemed to be saying that revisionist thinking about the two was somehow comparable—otherwise, why mention the Holocaust at all?

While listening to Mr. Brune speak at the Exploratorium, it seemed to me that in presenting the problem of ozone depletion in overly simplified, scarifying terms, Mr. Brune fed the public's fearful certitude about a matter that still requires a good deal more study to be well understood.

Finally, regardless of whether there is a "schism" between people trained in chemistry and those trained in physics, there is abundant evidence that an orthodoxy has emerged that stifles scientific dissent and skews support toward "right-minded" research.

Corrections

Dec. 1994/Jan. 1995 "Looking After an Icon" (In the Museum): The *Enola Gay*'s diameter is over nine feet, not 19 feet.

"Dreams for Sale": The cockpit photograph on p. 28 was reversed.

"Orion the Hunter": (1) We regret misspelling David Nelsen's name. (2) The photograph on p. 74 was reversed.

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Wild Rides at Edwards

BETHANN THORNBURGH

"Be prepared to inhale a lot of smoke and fumes," Captain Robert J. Wallace warned fellow students in a report last September after his first flight in a new aircraft at California's Edwards Air Force Base. Smoke and fumes? In 1994?

Wallace was the latest Air Force test pilot to fly a North American P-51 Mustang, which made its reputation 50 years ago and faded from active duty in Korea. Now Air Force student test pilots are getting a chance to check out in the legendary fighter as part of their training, and enthusiasm is rampant. As instructor pilot Ross Diehl said in his report, "The hoots and hollers can be heard over the engine."

"We're attempting to very robustly broaden the experience of all our students," says test pilot school commandant Colonel James Doolittle, grandson and namesake of the famed flier. "They're flying everything from F-18s to Stearmans and blimps with the intent of getting a guy who only has operational experience in a single, or perhaps two types of fighting airplanes, experience in about 25 different types."

Captain Bruce Rodger, staff instructor pilot and qualitative program manager, is charged with finding "exotic and unique" aircraft. "With airplanes today, we don't use the rudders because they're integrated with the computer," he says. "But with the P-51, you're constantly stepping on the rudder. Most pilots coming in now don't have that experience." Rodger has also recruited a PT-17 Stearman, a Douglas DC-3, and a Pitts.

For the dual-control P-51 flights, the Air Force contracted with Daryl Bond, a lumber company owner who flies his P-51D *Lady Jo* out of Chino, California. "The pilots enjoy it more than what they're flying," says Bond. "As one of them told me, 'This is work. We don't know what a stick and rudder is. All of our planes are automatically trimmed [to fly straight and level]. We just fly with our feet on the floor.' " Flight test reports are sprinkled with comments such as "Everyone should have the opportunity to fly one" and "Where do I buy one?"

Diehl thinks there's an additional, albeit unofficial reason that the Air Force's test pilots are being given stick-and-rudder time. He says, "The Navy has a more recent history of using propeller-driven airplanes," like the Beechcraft T-34 Mentor. "It would be kind of embarrassing for somebody to say, 'We got a propeller project' and have somebody say, 'Well, don't use the Air Force. They don't know anything about it.' "

—Bob McCafferty

Ollie, Oysters, and Mu'ammar

Every November, Alfred Scott throws a party. At his home across the Rappahannock River from the town of Urbanna, Virginia, Scott hosts a burgeoning fly-in that coincides with the town's biggest event. This year, Scott's party drew 25 airplanes and a crowd of 68.

Urbanna is famous for its annual Oyster Festival, a weekend-long small-town celebration complete with parading volunteer firemen, homecoming queens, and, this year, Virginia politicians: U.S. Senator Charles Robb and his opponents Oliver North and Marshall Coleman. What none of the politicians knew was that across the river at the Scott house, there was a high-profile no-show: Libyan leader Mu'ammar Qadhafi.

The rationale for the Scott party is to gather a variety of Stelio Frati-designed aircraft such as the SF.260 and Falco, although other types are "tolerated," in Scott's words (his company markets Falco

ERIC SCHULZINGER

The delivery of three Lockheed U-2S reconnaissance aircraft to the Air Force was marked by a ceremony held last October in Palmdale, California. Air Force pilot Chris Wheatley was greeted by Brigadier General John Rutledge, commander of the Ninth Reconnaissance Wing, after ferrying one of the U-2s from Lockheed's Skunk Works plant to Beale Air Force Base. The "S" designation applies to U-2s retrofitted with a new General Electric F118-GE-101 turbofan engine, which replaces the Pratt & Whitney J-75 that was installed in the aircraft in the 1950s. By 1998, all U-2Rs will have received the new engine, which permits greater range and altitude and enables a larger payload to be carried.

kits, but his brother arrived in a Cessna Caravan). Frati is a cult figure among light airplane enthusiasts, who admire his elegant, fighter-like two-seaters. Knowing that no one in the world has a niftier collection of SIAI-Marchetti SF.260s than the Libyan colonel himself, Scott wrote Qadhafi and invited him to the Urbanna bash.

"As you of all people know," the invitation read, "Stelio Frati is the designer of the...SF.260, of which you are easily the world's leading owner, operator, collector, and enthusiast. There isn't an American Frati lover who owns more than two, or perhaps three, of his designs...yet you alone own a staggering *one hundred ninety* examples of the revered marque!

"And well-armed examples they are, we must say," the letter went on. "There are those among us who pack a survival rifle now and again, but we all marvel at your superb collections of Frati-designed, rocket equipped sportplanes that literally can be called an air force. The Libyan Air Force, in fact."

It's uncertain whether Scott's letter ever reached the Libyan strongman; there was no reply. Scott seems prepared to forgive more than the snub, though: "Hey, if Sinn Fein is throwing in the towel, the Hutus and Tutsis are making up, the Palestinians and the Israelis are going to the mall together, it's about time we let bygones be bygones, right?" the letter concluded.

And then there's the matter of what the state department might have had to say about it....

—George C. Larson

UPDATE

Test Pilots Move Up

Two recent test pilot school graduates are among the 19 pilots and mission specialists NASA selected as astronauts last December ("Fast Track," June/July 1993). Pamela A. Melroy, a C-17A test pilot at Edwards Air Force Base in California, and Susan L. Still, a Navy F-14 pilot, are the second and third females to be named shuttle pilots.

North American's Salad Days

"It was a pretty ragged job, but it flew," said Lee Atwood, former president of North American Aviation, of the P-51 Mustang prototype. Atwood and other former executives and test pilots of NAA (later North American Rockwell) were gathered at the Santa Maria, California airport last August for the fifth annual reunion of NAA designers and builders. Sponsored by the Santa Maria Museum of Flight, which is seeking to house North American's papers and memorabilia, the four-day event drew about 5,000 people. Forty mostly North American aircraft, including a B-25, were on the ramp as Walt Spivak recalled, "We built 15 B-25s a day at the Kansas City plant, 31 P-51s a day at Inglewood. No vacations, seven days a week, 16 hours a day. My whole life was there." Spivak, Atwood, Ed Horkey, and others designed and built the first P-51 in just 117 days.

The P-51 may have been North American's greatest accomplishment, but the company also churned out T-6s, F-86s, X-15s, and the Mach 3 XB-70 bomber. North American has built more military

aircraft than any other company, including a total of 25,000 P-51s and B-25s.

Former test pilot Al Blackburn, who has flown more than 200 aircraft (but got his first ride in a P-51 at the reunion), recalls testing an F-86D over Los Angeles. "I wasn't minding the store and all of a sudden I'm pointed at downtown Long Beach and going Mach 1.04. I immediately pulled the nose up, pushed the mike button, and reported myself about 10 miles north of Palmdale," he recounted amid the laughter of North American veterans. "So I came home with a straight face. Next morning on the front page of the *L.A. Times*: 'Mysterious Blast Shatters Plate Glass Windows in Downtown Long Beach.' I think the statute of limitations has run."

Horkey, who as North American's first aerodynamicist had a major role in designing the B-25 and P-51, walked the Santa Maria ramp pointing to and explaining design features he and his team had

shaped in a wind tunnel. He seemed as excited about the hardware as he had been 50 years ago.

With assistance from Horkey and other North American vets, Blackburn is writing a book (*Macho a Macho Above the Mojave*) that claims that George Welch, not Blackburn's friend Chuck Yeager, may have been the first through the sound barrier. Speaking to more than 200 banquet guests, Horkey named several men who heard Welch "boom Muroc before Yeager" in an XP-86. "Welch's first child was born October 7 of 1947," he said, "and his wife called her mom and told her of both events" one week before Yeager's X-1 flight.

In the early 1950s, said Al Kustra, editor of *NAA Retiree News*, "North American bid on four government contracts: the X-15, a long-range interceptor, the XB-70 bomber, and the FBS fighter-bomber. Won all four, so we said to the government, 'Have someone else do the X-15.' The Air Force said, 'No, you won it, you do it.' The X-15 was the only one we finished."

—Bob McCafferty

Without a Net

At 8,000 feet over an airfield somewhere in Russia, the pilot of an Antonov An-2 biplane chops the power and flies just above stall speed. Bulked up by four layers of windproof clothing, a man slides back an emergency exit panel, hoists himself to a sitting position on top of the fuselage, and stands erect against the 70 mph slipstream.

Once he is sure of his footing, he makes his way to the tail. With slow and deliberate movements, to the rhythm from a Walkman beneath his woolly cap, he begins a ballet routine. There is no audience save the crew of the Antonov and a cameraman in a chase plane. And there is no parachute or safety harness. Herbie Pitts, self-styled "artist of the clouds," is indulging his obsession. "All you need for wing-walking," Pitts says, "is confidence, strong thighs, poor eyesight, and no dependents."

Frustrated by regulations in the West and by excessive costs everywhere, the 30-year-old Englishman used film industry contacts to find a pilot in Russia who would take him up to fulfill an ambition that was born in his teens when he read about American wingwalkers of the 1920s and '30s. The ambition became a calling, fed by spells in the Air Training Corps (a cadet corps for school boys), employment as an aircraft engineer, and part ownership of a Junkers Ju 52 that plied the U.S. airshow circuit. Pitts first tried wingwalking without a parachute while traveling to a show in Holland. He climbed out onto the wing on the pretense—had the authorities asked—of fixing a loose access panel.

Having sold all his possessions to gather the money to twice hire the Antonov, Pitts supports himself by doing gardening jobs in the affluent London suburb of Woking. All available cash goes toward wingwalking; little else matters. "The last trip I made I thought that a hotel and restaurant had been arranged," he says. "When I got there I found that I was staying in a mental asylum." He shrugs and grins. "It was okay, though." So far he has logged about 20 hours of fuselage walking in 15-minute bursts—about all he can stand before the cold gets to him.

Pitts hopes to develop a profitable business of licensing videos and stills of his aerial ballets. He has plans for a "really spectacular" performance this year involving bicycles and bathtubs. He is also trying to recruit a team of pensioners to parachute together at U.S. and

European airshows. "I had one bloke signed up but his family talked him out of it," he says.

What about the danger? "Listen," Pitts says, "I don't have a death wish. I do get scared—I don't like motorbikes or even flying very much. Anyway, it's sometimes more dangerous on the ground. Last week I set fire to myself when I was tending a garden incinerator."

—*Stephen Bloomfield*

UPDATE

Cosmic Close Call

Asteroid XM1, about the size of a small school bus, passed within 65,000 miles of Earth last December 9 ("This Target Earth," Oct./Nov. 1991). University of Arizona astronomer James Scotti discovered the asteroid by accident some 14 hours before its closest approach. Scotti had been observing a comet with the Spacewatch telescope on Arizona's Kitt Peak when he noticed the movement of another object.

Pedal Pushers

It looked more like collapsed scaffolding than an aircraft. Built of lightweight materials like balsa, carbon fiber, and aluminum, *Yuri I*, a Japanese-designed human-powered helicopter, made its U.S. debut in Seattle last August, one of the star attractions at a five-day International Human Powered Flight Symposium sponsored by the city's Museum of Flight.

In a hangar at Boeing Field, the helicopter's designer, Akiro Naito, and his Tokyo-based team readied the aircraft for a demo for some 200 Boeing employees. According to museum officials, *Yuri I*—a decade in the making—is the first human-powered helicopter to succeed in free hovering flight (see "Hover Story," June/July 1988).

Other pedal-powered craft slated to appear were not so fortunate. Neal Sakai's *Penguin* was crated and awaiting shipment from California to Seattle when Sakai's workshop was destroyed by fire, *Penguin* and all. Curtis Barnes' *Tipsy Bee* made it from Oregon to Seattle, but its pilot, Barnes' 12-year-old grandson, was unable to get it off the ground.

Among the onlookers in the hangar was Paul MacCready, whose pedal-powered *Gossamer Albatross* flew across the English Channel in 1979, winning the second Kremer Prize for human-powered flight. "These kind of aircraft look ridiculous," MacCready said as he watched the *Yuri* team set up. "They're so fragile and impractical. The goal, though, is not to build a practical vehicle but to change the way people think, to unleash creativity and push the boundaries. Ideas are more important than gadgets."

Yuri I's pilot was Norikatsu Ikeuchi, a slightly built 21-year-old student at the Tokyo Institute of Technology. Last spring the former Iron Man triathalon competitor kept his craft aloft for 20 seconds, his best flight to date.

Naito gave the signal and Ikeuchi came bounding out of a makeshift dressing room. Dressed in turquoise bike shorts and a T-shirt emblazoned with a sketch of *Yuri I* against a rising sun, Ikeuchi carefully climbed into the pilot's seat and put on bike shoes. Together, pilot and aircraft weighed under 200 pounds. As Ikeuchi began to pedal, the craft's two pairs of rotors slashed through the air. His teammates scurried out of the way, and Ikeuchi got the helicopter about a foot off the ground and began to drift, rather quickly, toward the crowd. Flight duration: 15.5 seconds. A second attempt clocked 24 seconds, beating his record.

As soon as he touched down, a grinning Ikeuchi jumped up and raced

through the crowd, giving high-fives to each onlooker. "I've been preparing for this flight for one year," he said in halting English. A reporter asked: "Did Dr. Naito give you any advice?" "No," Ikeuchi said. "He is just builder. I am pilot."

—Rita Cipalla

UPDATE

Latest X-Planes

In an effort to produce a fighter suitable for the U.S. Air Force and the Marine Corps, the Advanced Research Project Agency's common affordable lightweight fighter demonstrator has been designated X-32 ("The X-Planes," Oct./Nov. 1993). Lockheed's Skunk Works and McDonnell Douglas are both building mockups of the fighter, which will come in two flavors: the X-32A (conventional takeoff and landing) and X-32B (short takeoff/vertical landing).

The X-33 is the latest attempt to produce a low-cost reusable launch vehicle that would replace the shuttle. McDonnell Douglas and Boeing have teamed up to compete against other industry efforts, among them Rockwell and Lockheed. NASA is expected to name a winner next year.

One Out of Three

Robert "Hoot" Gibson's face told the story. Strapped in the shoulder-width cockpit of *Pushy Galore*, a gleaming yellow Formula One racer, Gibson smiled ruefully, raised his eyebrows, and slowly shook his head. During a flight over Galveston, Texas, last November, the astronaut/race pilot had failed to reach an altitude of 31,722 feet, which would have established three world records for class C-1a aircraft (piston engine aircraft weighing between 661 and 1,102 pounds). "It's like getting wounded," said *Pushy Galore* owner Bruce Bohannon. "It hurts, but it scars over and you come out tougher."

Still, pending certification by the Fédération Aéronautique Internationale, Gibson apparently established one new record, for time to climb to 9,000 meters (29,528 feet): 54 minutes, 15 seconds.

Gibson, who will command the shuttle

DAMOND BENNINGFIELD

Atlantis on a June mission to dock with Russia's Mir space station, tinkers with his own Formula One racer in his spare time. In 1991 Gibson set a world record for altitude in horizontal flight: 27,040 feet.

Bohannon flies *Pushy Galore* in several races each year, and last July he set a record for time to climb to 6,000 meters. But he and Gibson, who share hangar space in Friendswood, Texas, agreed that Gibson should try for the new records: time to climb to 9,000 meters, altitude in horizontal flight, and absolute altitude.

Pushy Galore, with its pointed snout and broad wings, looks like a cross between a pterosaur and a radio-controlled model airplane. Its 100-horsepower Continental engine drives a tiny pusher propeller that looks like it might be powered by a rubber band. Racing speed for the aircraft—the second fastest Formula One racer in the world—is 260 mph (Jon Sharp's *Nemesis* clocks in at 277). "It's very easy to fly," Bohannon says. "The handling is impeccable. Anyone who can fly a Cessna 150 could handle it."

For the record-setting flight, *Pushy Galore* weighed a mere 911 pounds at takeoff, including pilot, a video recorder to capture instrument readings, and 9.9 gallons of fuel.

Gibson took off in mid-morning as the first event of the Lone Star Flight Museum's "fly day." He circled the rows of World War II fighters and bombers, then headed toward the Gulf of Mexico to begin his climb. He spent about 10 minutes above 29,000 feet, trying to coax a bit more altitude out of the little airplane. But in the thin air, the 200-cubic-inch engine was producing only 45 horsepower, hardly enough to keep *Pushy Galore* flying. "The airplane was barely hanging in the sky," Gibson said.

Still wrapped in a heavy jacket and insulated boots, he added, "We may go back to the drawing board. At least now we have some data. We can compare that to our engineering curves and see what we need to do to try again."

—Damond Benningfield

UPDATE

Better GPS Accuracy

By mid-1996, civilians using the Global Positioning System for tracking and navigation can expect accuracy within three meters (10 feet) in certain areas of the United States, while surveyors and mappers will get even more precise data ("You Are Here," June/July 1992). A Department of Transportation report issued last December recommends that a combination of systems, held to a national standard, be used to augment the GPS signals.

Disk Drive

First it was the airplane in 1906. Then the helicopter in 1935. Now, for the first time in 60 years, the U.S. government has granted a patent for a new flying machine. George Neumayr, its 69-year-old inventor, says it could revolutionize transportation as radically as its predecessors. "Lay people would call it a flying saucer," says Neumayr, a retired Bell Aircraft design engineer. "I prefer to call it a flying disk."

Flying saucers of terrestrial origin have popped up in aeronautical history, most notably the twin-engine Vought V-173 "Flying Pancake" of the late 1940s, which, albeit saucer-shaped, was essentially a conventional aircraft, and the Avro Cana-

da VZ-9V Avrocar, a 1950s vertical-takeoff-and-landing (VTOL) hover craft powered by three turbojet engines driving a five-foot-diameter rotor. Both survive in the National Air and Space Museum collection but neither saw production.

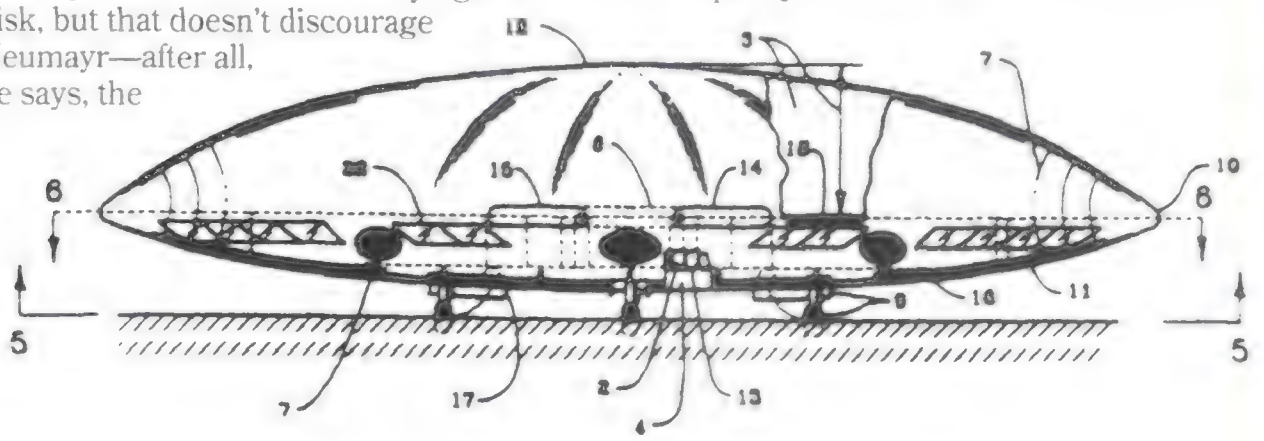
Neumayr says his flying disk will derive lift and thrust from eight jet engines positioned around the disk's perimeter, and directional control will be provided by computer-controlled rotating sleeves mounted in the jets' exhaust pipes, similar to the Marine Corps Harrier jet. It would take off and land vertically, eliminating airport congestion and the need for runways. For additional buoyancy, the disk will have a pocket of helium trapped beneath its solar-cell-covered upper surface. The size of such a flying disk would be up to the manufacturer, but Neumayr says that with a diameter of 200 feet, the craft could accommodate up to 1,000 people and fly at speeds comparable to today's airliners.

A native of Bavaria, Neumayr emigrated to the United States after World War II and joined Bell in 1951. Over the next 20 years he helped design VTOL aircraft like the X-14 and X-22, as well as guidance systems for the Mercury, Gemini, and Apollo programs. Though he conceived his flying disk 25 years ago, it was only in the last couple of years that he found time to design and patent it. "A flying disk of this type would increase the job market and provide a much-needed boost for the aerospace industry," Neumayr says.

Still, the newest flying machine exists only in patent drawings, and at least one expert isn't as sanguine about its future. "In extraterrestrial space that shape might be fine, but in the atmosphere you just can't beat a winged body," says Jan Roskam, a professor of aeronautical engineering at the University of Kansas. "You never want to be negative about an idea, but I'm very skeptical."

To date, so is the U.S. aerospace industry. No company has stepped forward to develop and manufacture the flying disk, but that doesn't discourage Neumayr—after all, he says, the patent was awarded only last October. Echoing the marketing strategy adopted by his predecessor, Wilbur Wright, Neumayr says, "If the U.S. doesn't want to buy it, then I will go overseas."

—Phil Scott



ERIK HILDEBRANDT

Rhinebeck's New Show

In August 1909, the world's first great fly-in and airplane competition was held in Reims, a city in the Champagne region of France. The excitement created by the pioneer flying machines gripped all who attended the Great Aviation Week.

Eighty-five years later, the spirit of Reims was brought to life again at the Old Rhinebeck Aerodrome in upstate New York. Rhinebeck is world-renowned for its World War I airshows, and the roar of rotary engines and the smell of castor oil are routine there. But last August, the cast of performers included the classic machines that appeared in the decade after the Wrights flew at Kitty Hawk.

Aerodrome personnel rolled out five early machines, and one by one the 80-plus-year-old engines were propped by hand and warmed up, including a three-cylinder Anzani in an original 1909 Blériot, an 80-horsepower Hall-Scott in a reproduction 1911 Curtiss Pusher, and a seven-cylinder Gnôme rotary in a 1911 American Aeroplane Supply House Blériot XI. "It's been 12 years since we've tried to fly the Gnôme Blériot," said Rhinebeck chief pilot John Barker.

First up was a 1913 Caudron G.III, a rotary engine wing-warping biplane that made three gentle takeoffs and landings (so fragile and underpowered are these aircraft that Aerodrome pilots dare not risk a circuit around the airfield). Then came the Anzani Blériot. With only 35 horsepower, the craft struggled to stay airborne. "Ladies and gentleman, I'm going to keep quiet and let the airplane do all the talking," said show announcer Jim Hare.

After performances by a Curtiss Pusher and a reproduction 1910 Hanriot monoplane, the crowd was primed for the Gnôme Blériot. But due to some last-minute landing gear and engine problems, longtime Rhinebeck pilot Dick King elected to only taxi it (the aircraft ended its 12-year hiatus the following weekend, making several flights during the standard airshows).

The Aerodrome staff plans to make the pioneer weekend an annual August event. Rhinebeck founder Cole Palen, who died in 1993, had a special place in his heart for the very early machines (see "That Magnificent Man and His Flying Machines," April/May 1994), and the sounds of the Anzani and the Gnôme over the Aerodrome strip signaled that Palen's legacy is alive and well.

—Peter Jakab

UPDATE

Crash Claims Museum Creator

Frank Ryder, creator of the World War I Replica Fighter Museum in Alabama (Soundings, Dec. 1994/Jan. 1995), was killed, along with his wife and son, when the family's Piper Malibu crashed shortly after takeoff last December 23 in Rochester, Minnesota. The Ryders were returning home from the Mayo Clinic, where son Scott had undergone successful surgical removal of a tumor on the pituitary gland.

All Busy on the Home Front

After Japanese warplanes attacked Pearl Harbor in 1941, Americans were left with a lingering sense of dread that Japan or even Germany would mount another surprise attack. So acute was this fear that the country created a coastal defense network to scan the skies for enemy aircraft and comb the seas for German U-boats. (The German threat, of course, was real: during World War II, many ships were sunk within sight of American shores.)

In remembrance of the men and women who kept diligent watch over the homelands, as well as those who helped arm the country for war, the National Air and Space Museum is mounting a photo exhibit that will open in April in the Pioneers of Flight gallery. "Building and Guarding the Arsenal of Democracy" features more than 40 photographs from the Museum's extensive collection.

Tom Soapes, a Museum archivist and curator of the exhibit, wants to illustrate the collaborative effort of civilians and the military to guard the coast. Accordingly, he has chosen an image that shows two civilians atop a New York City rooftop searching the skies for unidentified aircraft, as well as one that depicts Navy airships and Coast Guard airplanes patrolling the Atlantic for German subs.

Soapes also wants to educate Museum visitors about the great industrial buildup necessary to manufacture the aircraft, ships, armament, and munitions used for the battles the Allies waged in Europe and the Pacific. Between 1942 and 1945, the wartime economy spawned 17 million jobs, many of them filled by women. "A diverse workforce did develop here," says Soapes, who has included many images of women working on the production lines. "Rosie the Riveter didn't win the war single-handedly, but we couldn't have won the war without her." By the time the war ended, the United States had outproduced Germany and Japan, transforming itself into the most powerful nation in the world.

—Diane Tedeschi

Museum Calendar

Except where noted, no tickets or reservations are required. To find out more, call Smithsonian Information at (202) 357-2700; TTY: (202) 357-1729.

February 2 Black History Month Lecture. Brigadier General Marcelite J. Harris talks about the Air Force assignments she has held. Langley Theater, 7:30 p.m.

February 3–17 Space Fiction Film Series: Feb. 3, *When Worlds Collide*; Feb. 10, *Robinson Crusoe on Mars*; Feb. 17, *Star Trek II: The Wrath of Khan.* Langley Theater, 8:00 p.m. Admission $2.

February 4 Planetary geologist Robert A. Craddock of the Center for Earth and Planetary Studies discusses Mars. Einstein Planetarium, 9:30 a.m.

February 11 Cuban Air Force defector Orestes Lorenzo discusses his book *Wings of the Morning.* Pioneers of Flight gallery, 2:30 p.m.

February 15 "The History of the Hubble Space Telescope." Join author Robert Smith for an illustrated journey through the telescope's unique history. Einstein Planetarium, 7:30 p.m.

February 16 G.E. Aviation Lecture. "The Civil Air Patrol Serving America," Brigadier General Richard Anderson, National Commander, Civil Air Patrol. Langley Theater, 7:30 p.m.

February 18 "Follow the Drinking Gourd," a new planetarium show, illustrates the importance of the Big Dipper. Einstein Planetarium, 10:00 a.m.

February 22 Mary Henderson, associate director for art and culture at the National Air and Space Museum, discusses the 1960s television series "Star Trek." Einstein Planetarium, 7:30 p.m. Admission $2.

March 3 "A Poetry Reading Under the Stars." A Women's Air Force Service Pilot in World War II, Ann Darr reads from her new book *Flying the Zuni Mountains.* Einstein Planetarium, 7:00 p.m.

March 15 Heidi H. Hammel, an astronomer at MIT, discusses planetary astronomy. Einstein Planetarium, 7:30 p.m.

March 16 G.E. Aviation Lecture. Kathy LaSauce, the first woman Air Force pilot, will review her 22-year career. Langley Theater, 7:30 p.m.

March 19 "Build a Better Kite," a free workshop for families who want to build kites that really fly! Milestones of Flight gallery, 10:00 a.m. to 4 p.m.

During World War II Americans built thousands of aircraft at factories like this B-24 plant in Fort Worth, Texas. The war created new job opportunities for African Americans and women, who worked as navigators, welders, and ferry pilots. To guard the nation against attack, Americans searched the skies for enemy aircraft.

NASM (6)

WALTER CALAHAN

ON THE MALL

On March 25 the Smithsonian Associates will hold their annual Kite Festival. Last year, kites weren't the only objects sailing through the air above the Mall. The sky rained teddy bears as well. "Bear dropping" is a popular sport in England, but the United States has a few aficionados of its own. One of them is kite maker Michael Dallmer of Philadelphia. Each summer he and his family attend kite festivals with a menagerie of 14 bears.

Dallmer, who makes and clothes all of his bears, can drop five at once from his largest kite. Each bear is attached to the kite line by a release. A jerk on the line opens the release, allowing the bear to fall two or three feet before the rip cord pulls the pin on its parachute. Dallmer usually drops his bears from an altitude of 300 to 400 feet. "It all depends on the surroundings," he says, "because I don't want to lose a bear in a tree." Dallmer has a good record of bear recovery, but just like real parachutes, his teddy-sized versions don't always open. "We've killed a few bears," Dallmer admits.

The Big Creek Missile Agency

In 1957, Coalwood, West Virginia, was a miner's town, a dusty coal camp in a narrow valley surrounded by high, heavily forested ridges, the sky a narrow swath between them. I still think of the black-helmeted miners who every morning tramped along the path to the Olga Number One shaft, heavy denim pants tucked into steel-capped boots, lunch buckets swinging from calloused hands. Life in Coalwood seemed changeless, its center for me and its 1,200 inhabitants a deep shaft that plunged into a rich seam of bituminous coal. But when I was 14, an event in far-off Kazakhstan profoundly affected everyone in Coalwood: the Soviet Union launched Sputnik 1. The townspeople went out into the crisp autumn night to watch the first man-made satellite streak overhead. We were mesmerized by the sight; it seemed like some new and wonderful age had begun. Some of us even began to build rockets.

Roy Lee Cooke, Jimmy Carroll, Quentin Wilson, Sherman Siers, Billy Rose, and I had grown up together. We'd been in the same Boy Scout troop and built forts, attended dances, gone to church, and chased the same girls. All our fathers worked in and around the mines, as had their fathers and grandfathers. Before Sputnik, we were headed for the mines too. Now, suddenly, we were looking in a different direction: up.

Up meant rockets, and we wanted to build one. Rocket-building manuals being scarce, our first attempt was based on an illustration in *Life* magazine. We took a flashlight casing, punched a hole in its base, filled it with powder from 30 cherry bombs, stuck a fuse through the hole/nozzle, and used the top of my backyard fence for a launch pad. It was a cold, clear evening, ideal for tracking a rocket across the night sky. Liftoff was a huge ball of fire. However, it wasn't our rocket that lifted off, but the fence. Mom came out on the back porch and contemplated the smoking ruin. "Somebody's in trouble," she sang out. Dad came out too, and in effect demanded a body count. We replied with quivering voices that we were all still alive.

The failure of our first launch clearly demonstrated that we didn't know enough. Until Sputnik, we had been indifferent to science and math, neither seeming to have much to do with our future. Our chemistry and physics teacher at Big Creek High School, Miss Freda Riley, worked desperately hard, often buying teaching supplies with her own tiny salary. Down the hall, Mr. Lockhart, our math teacher, had long since given up capturing the interest of his students and had taken to giving lectures with his back turned, scrawling equations across the blackboard. Now, suddenly, both teachers had students who were not only interested but intensely interested. Mr. Lockhart had been around too long to be overly impressed, but Miss Riley was enthralled by her suddenly attentive charges. Her classes became ever more inventive. She brought in flatirons and wooden boats to demonstrate Archimedes' principle, balloons and bicycle pumps for Boyle's law, and yo-yos to explain centrifugal force.

Our first 11 rockets failed, which taught us that sometimes things have to be learned the hard way. Dodging aluminum shrapnel, for instance, was an excellent way to discover that the rocket casing would have to retain a certain amount of pressure. It also demonstrated that rocket propellant would have to burn slower than cherry bomb powder. We also learned about rocket nozzle design by discovering that the diameter of the hole in the bottom dictated whether the rocket would blow up or just lay on its side and spew. Somewhere in there was the right nozzle throat diameter, if we could just learn to calculate it. Suddenly, Mr. Lockhart's plane and solid geometry classes had some pertinence, and we astonished him by asking sensible questions.

COURTESY HOMER H. HICKAM JR.

Members of the Big Creek Missile Agency make ready to launch a rocket. From left to right they are "Sonny" Hickham, Quentin Wilson, Roy Cooke and Jimmy Carroll.

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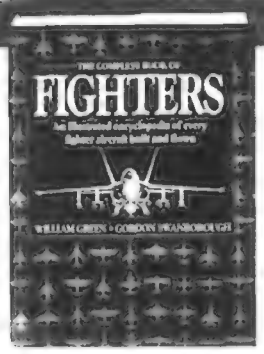

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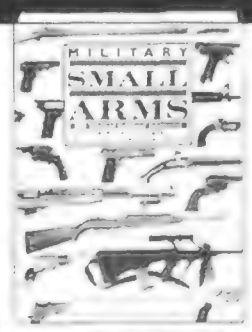

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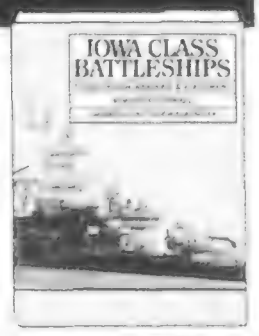

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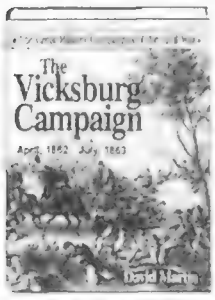

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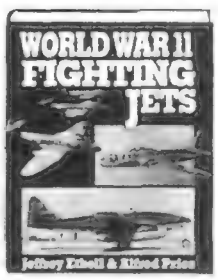

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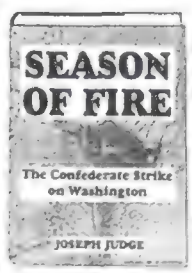

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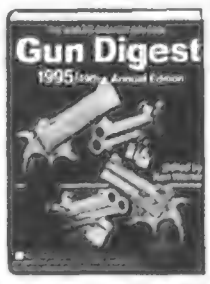

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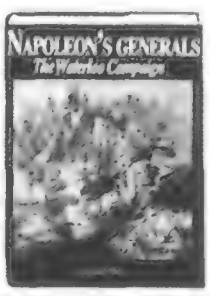

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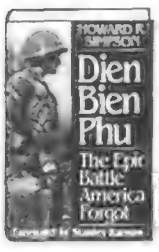

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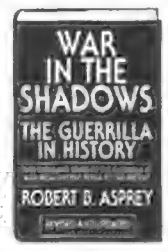

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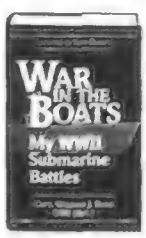

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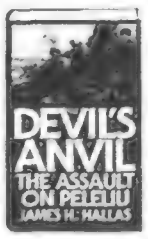

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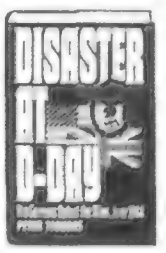

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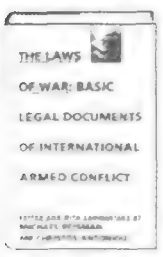

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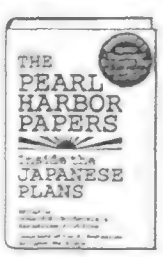

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Despite our new academic interests, our failures in the field were so steady that we named our rockets after the great auk, a bird that could not fly. But we were learning to be methodical, building on what worked, changing what failed.

Auk XII was our first success. A foot-long, inch-wide aluminum tube filled with potassium nitrate and sugar, it flew to the giddy altitude of 100 feet. We'd gotten the idea for the propellant when Miss Riley had used it to demonstrate rapid oxidation. When we saw that hot pink flame, we Coalwood boys shared knowing glances. *Rocket fuel!*

Potassium nitrate, otherwise known as saltpeter, was available at the company store, and sugar was in the pantry. We mixed it half and half and then went up and down the scale, looking for the best burn rate. After each mix we tossed the results in the coal-fire water heater in my basement. One day Mom was leaning on her new fence, talking to the neighbor, when our best combination went off, sending a spout of flame and smoke up the chimney with an impressive *whoosh!* Mom poked her head in the basement and informed us that, once again, somebody was in trouble. We sheepishly clanged the heater door shut. Dad later collared me as I headed outside. "Going to burn the house down?" he asked. "No sir," I said. "Attaboy," he replied.

Every weekend we would try our latest design. Our launch pad was a hollow behind the mine. "Is it going to work?" the miners would yell as we went past. When we showed them what we'd built, they'd grin and shake their heads. We were getting attention that had previously been lavished only on the football team.

When one of our rockets ricocheted off a tree and chased us through the woods, we decided we needed a true range and settled on an abandoned slack dump. Situated between mountain ridges, it was nearly a mile long. The coal mine supervisor—my father—okayed our using the dump and a little company lumber to construct a blockhouse, but he made it clear that that would be the extent of Olga Coal Company's assistance. The property was for mining, not for flying off into near-space. Still, anytime we needed something for our rockets, somehow it would just appear on the back porch.

Gaining national attention at that time was a gutsy group that seemed to be making great strides in rocketry. Wernher von Braun's team in Huntsville, Alabama, was known as the Army Ballistic Missile Agency—ABMA. We dubbed ourselves the Big Creek Missile Agency—BCMA. My parents wrote the

great man himself, asking for an autographed picture. It came with a note: "If you work hard enough, you will do anything you want." The BCMA had been sanctioned by an unstoppable force. We were written up in the newspaper as "the rocket boys." I was invited to speak to the Kiwanis Club, and, representing the BCMA, I took our designs to the National Science Fair.

During our last year of high school we pushed our saltpeter-and-sugar rockets as far as they would go, noting that there was a definite limiting factor as we increased the size of the rockets to gain altitude. We began to search for better propellants and delve into equations involving specific impulses and mass ratios, information not found in high school texts. Miss Riley provided the book we needed: *Principles of Guided Missile Design* by Bonnet, Zucrow, and Besserer. I still have it.

In May 1960, we launched *Auk XXXI.* It stood just over five feet tall and was 1.75 inches in diameter, had an electrical ignition system and aluminum fins bolted to the base, and was constructed of steel tubing with a nozzle and top plug machined from steel bar stock. We used zinc dust and sulfur as our propellant, and the steel nozzle had a throat diameter that had been calculated for maximum exhaust velocity. A converging-diverging design, it had been shaped on a lathe in the mine machine shop by a helpful machinist. To avoid erosion, we had lined it with an ablative ceramic. The nose cone was turned in the mine carpentry shop and fitted into a recess at the top of the casement. There was a vast gulf between this rocket and the backyard fence bomb we had built just a couple of years before.

At least a hundred miners and their families were on hand for the launch of *Auk XXXI*, each with a tale of how they had helped us in some way. The rocket flew perfectly, its smoke tracing a thin white line on the bright blue sky. By using homemade theodolites and applying some trigonometry and Newtonian physics, we were able to roughly calculate its altitude. *Auk XXXI*, the last rocket of the Big Creek Missile Agency, rose nearly four miles.

All of us rocket boys would go on to graduate from college, something not likely in pre-Sputnik West Virginia. Roy Lee became a banker. Jimmy went into insurance and farming. Quentin, Billy, and Sherman became engineers. I became a NASA manager at the Marshall Space Flight Center, von Braun's old headquarters. Though I now work with astronauts and often see shuttle launches, nothing will ever compare to seeing an *Auk* leap into the air, propelled by the dreams of boys and the kindness of a small town.

—Homer H. Hickam Jr.

Speech Lesson

When I took off at night for the first time, flying a BT-13 from Majors Field in Greenville, Texas, in 1943, I found myself in a strange, dark world. I was disoriented within minutes. For the next couple of hours I was a lost soul over darkest Texas, looking for something that looked like runway lights so I could bring the BT-13 down right side up and thus stay alive. Finally, I found a runway and got the thing down.

After I landed in what turned out to be the town of Terrell, I had to wait half an hour in Operations until another BT-13 from Majors Field landed and Lieutenant Kroll walked through the door. Kroll was a black-haired cloud of gloom with the build of a running back. Nobody had ever seen him smile. At Majors Field he gave elimination rides—E-rides—to cadets who showed some deficiency in flying skills.

"Follow me back," he said without looking at me.

I got back in my airplane and followed him through the dark for the 20 minutes it took to get to Greenville. During the last few minutes I watched his wing lights making small circles, then larger circles, and knew he was doing slow rolls and barrel rolls.

At Majors Field, Lieutenant Clapp was sitting behind his desk. Clapp was in charge of discipline and everything else in the lives of cadets. "How'd you manage to do anything so stupid?" he asked.

"No excuse, sir," I said. It was the required cadet response.

"I don't know what you ought to do," he said. "Maybe 10 or 20 hours of walking tours."

Walking tours was a traditional punishment. You wore white gloves and a Class A uniform and marched up and down with a prop rifle on your shoulder for the specified number of hours.

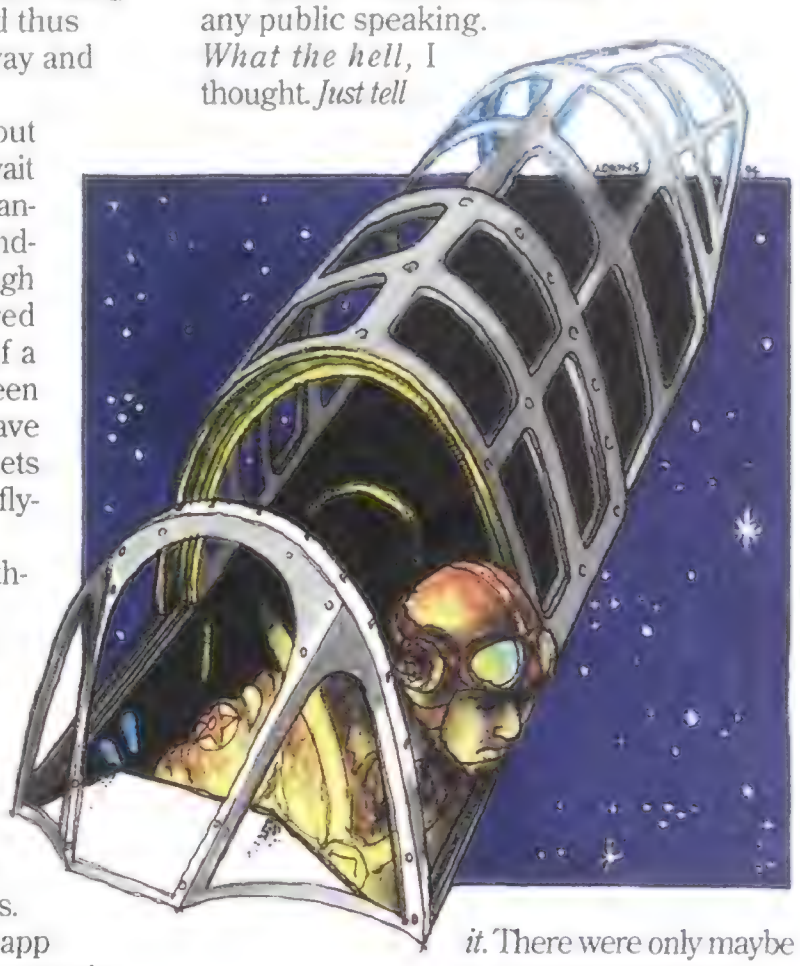
I kept my mouth shut.

"I have a better idea, Mister," Clapp said. "I think you'll give a speech about your stupidity at lunch tomorrow."

"I'd rather walk tours," I said. "Nobody asked you," he replied.

The next day, toward the end of lunch, Clapp stood up in the mess hall and rapped a spoon on a glass. "Cadet Benson has an educational talk for all of you," he said, then sat down.

I stood. I had never done any public speaking. *What the hell,* I thought. *Just tell it.* There were only maybe 150 guys in the room.



JAN ADKINS

"Last night I took off from Auxiliary Field Number Two at 8:03," I began. "At 8:04 I was lost." I heard a lot of loud, happy laughter and some pounding on tables and immediately felt better.

"After I got out of the traffic pattern I couldn't find Auxiliary Field Number Two and I couldn't find any goddamn runway at Majors Field," I said. More laughter.

I had a thought. Most of the guys were from the northeast. "I flew around for a while looking at Texas," I said. "Texas looks even worse in the dark than it does by daylight." That drew some applause. "I found Dallas and I found Love Field, but I didn't have the radio frequency of the tower there. I figured it would be suicide to get into their landing pattern in a BT-13 without an invitation. So I said goodbye to Dallas." Sympathetic laughter.

"I flew around and looked at Texas some more. I was hoping to find a lighted runway, but when I'd drop down to something that looked promising, it'd turn out to be the main street of some little town." I remembered something. "There's a Spencer Tracy movie playing not far south of here." That got more laughs and some rapping on glasses.

"I finally gave up on trying to find some place to land in the dark in Texas," I said. "I climbed to 5,000 feet and got ready to bail out. Then I started doing some arithmetic, trying to figure out how long it would take me to pay for a BT-13 at $75 a month"—cadet pay. "I dropped back down to 3,000 feet and looked for a runway some more. And I found one, a sure-enough runway. I buzzed the tower and got a green light. After I landed and parked and cut the engine, someone climbed up on the wing and asked me where I was from. He had a British accent. I knew I'd been flying a long time but I didn't remember crossing any water." Belly laughs. "Turned out I had landed at the field in Terrell where some Royal Air Force cadets are taking flight training. The guy with the accent wanted to know if a man named Muldoon still sold bootleg whiskey at the hotel in Greenville. I told him yes, five bucks a pint. 'Used to be four,' he said. Anyway, Lieutenant Kroll came down to get me and I followed him back to the field here in the dark. Lieutenant Clapp did not appear happy to see me, and suggested that I give this little talk."

I waited a moment, then said, "If you ever get lost at night, what you should do is climb to 5,000 feet and bail the hell out. That way, they'll shoot you at sunrise and you won't have to make any speech."

I sat down to applause and a lot of banging on tables. I looked over at Clapp, who was laughing, and saw something no one else could ever recall: Kroll was smiling.

—Arnold Benson

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Fans of aviation's Golden Age will do whatever it takes to get their favorite classics back in the skies.

by Phil Scott

Photographs by Erik Hildebrandt

ARCHIVAL PHOTOGRAPH, FROM NASM

SOMETHING GOLD, SOMETHING NEW

At last year's fly-in at Oshkosh, Wisconsin, Golden Age racer aficionado Bill Turner showed off his most complex undertaking: a replica of a de Havilland D.H.88 Comet (opposite, top). Turner modeled his craft on the winner of a 1934 race from England to Australia (opposite). Originally named Grosvenor House, *the racer went through a series of name changes, culminating in* Australian Anniversary *(above). Today it bears its original name.*

At last year's Experimental Aircraft Association fly-in at Oshkosh, Wisconsin, a red airplane parked in the classics section was attracting passersby like a streetlight draws moths. Low and mysterious, with two engines and a long, lean snout, the craft resembled a de Havilland Mosquito, but with more of a pre-war, Art Deco look. A questioning murmur rose from the group: The machine was gorgeous; it looked, uh, classic all right, but what was it?

As its pilot, Bill Turner—tall, thin, and dressed in a red flightsuit that matched his airplane—crawled down from the cockpit, curiosity overcame one onlooker. "Excuse me, sir," he asked, "but what *is* this?"

"This is a 1934 de Havilland Comet," Turner explained proudly, "from the Golden Age of Aviation."

The Golden Age of Aviation—it's a warm, idealized term for the period between the world wars, when spindly open-cockpit biplanes were evolving into sleek all-metal monoplanes, and the machines breaking records for speed, distance, and endurance were not produced by the military or the government but by lone designers and racers desperate to capture the next prize.

Because the 1920s and '30s was a time of economic depression and military inaction, the aircraft of the Golden Age did not roll out of the plants in great numbers. During the 1930s, Curtiss, for example, built a mere 46 copies of the P-6E Hawk fighter. The Weaver Aircraft Company turned out only 18 Waco YMFs, a beautiful two- or three-seat biplane designed for recreational flying. And, as Bill Turner neglected to explain to his questioner, de Havilland built only five Comets, and though the sole survivor is still in flying condition, it is housed in a British museum.

So where did Turner's come from? Like other Golden Age fans, Turner decided that if he couldn't own and fly the real item, he would get himself a copy.

Turner is at the heart of a return to the Golden Age that has been gaining momentum over the last 20 years. He was

actually present for much of the original era. During the '30s, his father, a member of the Navy's elite High-Hat fighter squadron, would take young Bill to the pilots' pit at the renowned National Air Races in Cleveland. "I knew all the great race pilots—as a kid knows an adult," he says. "I used to sit in those great machines and think, *Oh God, if I could just fly one of these*. Well, I've got five of them now."

Turner, a naval aviator in World War II, had learned woodworking by building race cars for the Chevrolet-sponsored All-American Soapbox Derby. In the early 1970s he cut his plane-making teeth on a modern homebuilt design called the Bowers Fly Baby. He went on to help build a duplicate of the graceful little *Miss Los Angeles*, a racer designed by Lawrence Brown that had placed second in the 1934 Thompson Trophy speed race. Later he restored the original *Pete*, a tiny white streamlined monoplane that had come in third in the 1930 Thompson. Then, around the time he retired as a dean at Hastings College of the Law in 1978, Turner formed Repeat Aircraft in Riverside, California, and began building Golden Age racer reproductions for himself and others, one at a time: the blunt and brutal Gee Bee Model Z, christened *City of Springfield* and winner of the 1931 Thompson; the Miles & Atwood Special, a green single-engine monoplane that had competed between 1933 and 1937; and his latest and most complex, an exact copy of the *Grosvenor House*—that big bullet-shaped de Havilland D.H.88 Comet, winner of the hotly contested 1934 London-to-Melbourne race. His customers are men like Tom Wathen, chairman of the board of the Pinkerton detective agency. Wathen owns the Comet, but because he hasn't racked up enough flying time in such a high-performance craft, he leaves the flying to Turner and Turner's backup pilot, retired Air Force general Patrick Halloran.

Turner's business continues to grow. This spring he will begin building a replica of the jaunty Wasp-powered 1932 Springfield Bulldog, and he plans to build himself a Turner-Laird Special, a thin, muscular racer whose cantilevered wing had been designed by Matty Laird. Commissioned and flown by racing legend Roscoe Turner (no relation, though Bill once knew the pilot as "Uncle Roscoe"), the original Special had placed third in the 1937 Thompson and first in the '38 and '39 contests. The replica builder has also fielded serious inquiries for such machines as Howard Hughes' 1935 H-1 racer, a sophisticated, slender design with two interchangeable sets of wings, one for sprints and one for long distances.

The hoops Turner must jump through to produce his airplanes are surprisingly few. Because the Federal Aviation Administration classifies these reproductions as "Experimental," it does not hold them to the same stringent construction criteria it applies to conventional commercial craft. (However, the replicas must display placards in their cockpits warning that all aboard fly at their own risk.) And as far as sources goes, Turner rarely has to hunt down design plans, for the simple reason that few Golden Age racers were built from them. Instead, he studies historic photographs, especially those showing the aircraft under construction.

Turner is also active in the flying end of the Golden Age revival. For this year's Oshkosh convention, he is organizing a Golden Age racing exhibition, and he has commitments from at least 25 pilots. "We'll have more there than ever flew at the National Air Races all at once," he says.

One of the biggest hits at the exhibition will surely be a stubby red and white Gee Bee R-2 Super Sportster. The original R-2 and its close cousin the R-1 had both competed in air races in the '30s—and both ended up as smoking heaps of scrap. A few years ago, Montana wheat farmer Delmar Benjamin and his partner Steve Wolf set out to construct a replica R-2. "Part of the reason I wanted to build it was because there were 60 years' worth of wild stories about this plane, but nobody had flown it for that long either," says Benjamin, his voice quiet and raspy but friendly. "I thought I should do it. It is a dangerous plane, there's no doubt about it. Anything that stalls at a hundred knots and has the glide ratio of a manhole cover is not a safe airplane."

The Gee Bee is an extreme example, but other Golden Age racers are also tricky to handle. Bill Turner is rebuilding two of his own replica racers, the Miles & Atwood Special and *Miss Los Angeles*, which were recently crashed by

other pilots, both of whom were seriously injured. (Eerily, the Special crashed 47 years to the day after the original did.) "To people who want to build a Golden Age air racer," he says, "I always tell them to keep in mind—what was the name of that old Groucho Marx television show?"

You Bet Your Life?

"Exactly."

If Bill Turner is the Father of Golden Age racer replicas, then Herb Tischler is Father of Golden Age fighter reproductions. Tischler got in the business in 1971, when an Eastern Airlines captain, Ted Vorhees, walked into his metal shop holding a few scraps of a 1928 Boeing P-12, a trim, single-seat Navy fighter biplane that had been powered by a 500-horsepower Pratt & Whitney engine. Vorhees pointed to the aluminum elevator's corrugations, which were

closed at the ends. "Can you do this?" he asked.

"Let me give it a try," Tischler said. "It will cost you, however."

"Sure," said Vorhees.

As Tischler now recalls, "Not many Americans are able to do this type of work, but I am willing to try." A native of Bavaria, Tischler began learning his craft in 1941 as one of 400 apprentices at the Henschel factory in Berlin. After the war, Tischler joined the U.S. Air Force and repaired aircraft in Germany. He eventually made his way Stateside, where he set up his own shop, rebuilding helicopters under contract. That's where he met Vorhees (now deceased).

Tischler, his thinning gray hair plastered back, is on the small side, except for his mid-section, which seems to be held in with a pair of taut, colorful suspenders that would be at home holding up a pair of lederhosen. As he recalls it, "When Captain Vorhees showed up later and saw my work, he was full of fire—'Let's go!' he said." Working from drawings and specs Vorhees had obtained, Tischler set to work building the fuselage and landing gear for an entire P-12. (The wings were fashioned by Michigan woodworker Arnold Nieman.)

Shortly after Tischler took on the P-12, word of his project reached Omaha tool-and-die manufacturer Ralph Rosnick. Rosnick had been in love with the elegant 1932 Curtiss P-6E Hawk since seeing one on a Depression-era airport ramp, and he had tried for years to gather up enough of a Hawk to rebuild. When he heard about Tischler, he hounded him until the craftsman agreed to set aside the P-12 and move to Omaha to fabricate all the metalwork for a new Hawk, piece by piece, from original factory drawings.

"I was placed alone in a shop in his basement," Tischler

Delmar Benjamin wowed the crowds at Oshkosh with his reproduction of the Gee Bee R-2 Super Sportster (opposite and left). The R-2 was one of a line of ornery little racers produced by the Granville Brothers. Another Gee Bee, the Model Z City of Springfield *(below), which won the 1931 Thompson Trophy, caught the interest of Bill Turner, who built a replica of it.*

recalls. "He forced me to build the best thing that I could—he would come in and look at a part and ask me if I could do better. Of course, as a German I know I am never satisfied with my own work, and I would start over." For two years he labored until the machine was nearly done. Then Rosnick fell into business trouble, which forced him to crate up the P-6E and hide it away. (Tischler, meanwhile, moved back home and completed the P-12.) Today, the Hawk is finally assembled.

In 1976, Tischler, once again rebuilding helicopters, met Doug Champlin, director of the Champlin Fighter Museum in Mesa, Arizona. Champlin had once owned the only flying Grumman F3F, a chubby 1930s Navy fighter that was the last biplane to be operated from carriers. Unfortunately, Champlin's craft had crashed at a 1971 airshow, and the collector felt terrible about the loss of such a historic machine. After he met Tischler, he got together several backers and commissioned the craftsman to rebuild his F3F, plus build three new ones.

Using original Grumman plans and the debris of three F3Fs that had flown into the side of a Hawaiian mountain back in 1941, Tischler set up the Texas Airplane Factory at Fort Worth's Meacham Airport, hired a small staff of metal-benders, including his son, George, an aeronautical engineer, and started cranking out hand-crafted parts. By 1992, after nearly four years of work, Tischler had assembled three single-seat F3Fs and rebuilt Champlin's two-seater—all duplicates of the 1935 design save for a handful of modifications: a more powerful engine, modern avionics, and disc brakes instead of old-style, unreliable drum brakes. The cost: close to $300,000 apiece.

Tischler's productivity has become legendary among replica builders. One, Gene Oshran of Long Island, New York, admits to finding the senior craftsman's efficiency unnerving. Oshran has put eight years into his project, a—well, he would rather not say, because as far as he knows, his is the only replica of it under construction, and he desperately wants his to be first to fly. "I have a dread of someone beating me to it," he confesses. "People like Tischler scare the hell out of me. He could turn out five in less than two years."

Fortunately for Oshran, Tischler has for the moment turned away from Golden Age fighters. Today, the floor of his plant—a dark, cavernous hangar at Meacham Airport—is covered with jigs labeled in both German and English, raw metal stock, and airplane parts of all shapes and sizes, painted with flat epoxy primer and precisely stacked together in sets of

DAVID LEESON

Herb Tischler has applied his Teutonic craftsmanship to reproductions of some of the U.S. military's more sporty-looking aircraft, such as the F3F (left), the last U.S. biplane to serve on carriers, and the P6E Hawk fighter, a squadron of which performed at the National Air Races in 1932 (above).

five. Taking shape from those stacked parts are five brand-new Messerschmitt Me 262 fighters, the first jets to be used in combat. (Tischler has become a celebrity among surviving 262 pilots, his boyhood heroes.) After that, Tischler will fill an order for several World War II Focke-Wulf Fw 190 fighters, and then—who knows?

Though the American economy was in shambles in the 1930s, several thousand airplanes were licensed for private, recreational use, and according to an article in a 1936 issue of *Western Flying*, the largest number were produced not by Cessna, Piper, or Beechcraft but by the Weaver Aircraft Company, known by the acronym Waco (pronounced WAH-co). Having survived the Depression, Waco, like many a venerable manufacturer, found itself drowning in a glut of aircraft after the war. The company gave up making airplanes and took up building log-splitters and other products.

Nearly forty years after the last Waco came off the production line (and during a recession in both aircraft and automobile manufacturing), Richard Kettles, then a Cessna

dealer based in Lansing, Michigan, began casting about for a project that would supplement his business and also help out a few unemployed auto workers in the area. Along with his son, Don, he hit upon the idea of manufacturing a line of classic radial-engine biplanes. "We asked pilots 'What was the best open-cockpit biplane ever built?' " recalls Don, "and anyone who had ever flown the Waco YMF said: 'This is the airplane.' "

The Kettleses searched for an original to restore and use as a pattern. Waco had built only 18, and when they finally found one, they discovered that its measurements showed far more variability than would be permitted in today's craft. So they went to the National Air and Space Museum's archives and got copies of the biplane's plans. Back in Lansing, they leased an old paint shop just off the Capital City Airport (Don jokingly refers to the shop as "Factory Number One"), as well as a hangar on the airfield ("Factory Number Two") for final assembly. They set up a short production line, hiring auto workers and former employees of the old Piper factory at Lock Haven, Pennsylvania. Since 1985 the Kettleses' Classic Aircraft Corporation has turned out 62 Wacos, priced at upwards of $200,000 apiece (the originals sold for $7,000). There are no huge robot welders throwing off sparks here: Each machine is crafted by a small swarm of workers welding steel, stretching, doping, and sanding fabric, and threading wires and cables.

Still, why would anyone want to spend nearly a quarter-million for an open-cockpit biplane?

"It reminds folks of a time when everything was more fun and people knew their neighbors," says Don Kettles. "Flying then was different, and people want to experience that kind of flying—once you've flown a Waco, you know you have flown a real airplane. And when you roll up onto the ramp, you own the airport."

Though Classic Aircraft started out building nearly exact replicas, over time it has added at least 250 modifications to the design—lengthening the fuselage for longitudinal stability, adding a balanced rudder, widening the cockpits and enlarging the forward door (today's pilots, it seems, are larger), and replacing the drum brakes with the disc variety. "It's a 1930s airplane built to 1990s standards," says Dick. In other words, unlike the reproduction fighters and air racers, almost any pilot can fly one. And the Kettleses are happy to let potential customers try out the merchandise for themselves. (They recommend you forget about all that romantic leather gear and wear a lighter and warmer vinyl-filled jacket. For an authentic touch, they will lend you an old-fashioned cloth helmet for your test hop.)

Maybe it's only because you're sitting out in the open, but the Waco seems bigger than a modern small airplane. There's a nice thick wood-and-fabric wing below, another one above, and a view unhindered by plexiglass; if it weren't for all the wind and wires you might think you were on Grandma's front porch. And like a front porch, it's not going anywhere in a hurry. The Waco Classic plods along at around 120 mph, so the Kettleses recommend their customers fly low and enjoy the view.

Not all Golden Age resuscitations end as happily as the Waco's. After a much ballyhooed revival of the Super Cub, a perky yellow descendant of the J-3 Cub, Piper has recently announced that it is once again ceasing production. (The nostalgia craze has been so strong, however, that industry wags claim that Piper makes more money selling Piper Cub T-shirts than it does selling modern airplanes.)

And in 1989, John Polychron, a retired president of the Planters LifeSavers Company, bought the old Taylorcraft airplane company, which had manufactured high-wing, two-seat monoplanes from the 1920s to 1946. Polychron was counting on a predicted upswing in general aviation sales, but after making and selling just 14 new Taylorcraft, priced at a low $50,000 to $60,000 each, Polychron put the company back on the block, pleading a lack of funds to properly market the line. Despite his setback, he maintains that yesterday's design has a bright future: "People will say, 'That's old technology.' My counter to that is, it's good, proven technology. All its basic problems are worked out—if you want new technology, add modern avionics."

When all is said and done, what's really behind the Golden Age revival? "It's a bit of escapism," maintains model builder Gene Oshran. "The times were simpler. They weren't better, but perhaps they were easier to understand. The country was still reveling in Lindbergh's flying feats, and the Army Air Corps hadn't lost sight of the fact that colorful airplanes were good PR. It was a different time. Army pilots could even fly their airplanes home on weekends. Could you imagine that kind of philosophy today?"

"It was a pretty dull era, as I lived through it as a kid," says Bill Turner. "Folks sought out heroes, and here were people going faster than human beings had ever traveled. It gave us an outlet.

"The times also showed what people will do above all odds," he adds. "I think it's a good look into the American psyche: We have to be pressed to do well."

In Lansing, Michigan, Don Kettles (left) and his father Dick, assisted by a small team of workers, turn out reproductions of the Waco YMF, a homey little craft that the Weaver Aircraft Company produced in the 1930s for recreational flying (below). The replicas' cowlings are fashioned with flared indentations that fit snugly over the engine's valve covers (opposite).

HEAVENS ON EARTH

You don't always have to go into space to do space science. Sometimes all you need is a good hole in the ground.

by Bennett Daviss *Photographs by Bruce Zake*

Technicians at the Zero Gravity Research Facility at NASA's Lewis Research Center ready a payload capsule for another 430-foot free fall. During the plunge, the contents of the capsule experience a five-second foray into weightlessness.

"Master switch on," facility manager Dennis Thompson commands. Across the control room, the technician at the console snaps a toggle. "Master switch on," he confirms.

"V-One on." The technician flips another switch: "V-One on."

For the next 20 seconds Thompson and the technician work through a series of commands, opening and closing valves. Then Thompson radios a command to a technician on the other side of the observation glass. From a scaffold 18 feet above the floor of the sunlit, hangar-like bay, he responds by sliding two steel pins from their housings and turning a handle. "Safety pins pulled and locked out," he radios back, moments before the five-second countdown begins.

The mission this morning is not to launch a payload into space but to drop it 430 feet down one of the world's most sophisticated holes in the ground. At zero, a sharp *pock!* resounds through the control room, like the sound of a bowling ball clipping a distant tenpin: the payload's single restraining pin has been snapped under hydraulic pressure. An image of the 2,000-pound payload capsule flashes across the booth's bank of video monitors as the pod accelerates to a speed of 120 mph. Five seconds into its mission, the capsule disappears into an oversize barrel filled 20 feet deep with granulated styrofoam. A few seconds later, a thudding echo rumbles up from underground.

Thompson's sleepy eyes brighten. "That's research!" he says cheerily, scribbling notes into his logbook.

This is the Zero Gravity Research Facility, a shaft beneath a nondescript building at NASA's 300-acre Lewis Research Center on the edge of Cleveland, Ohio. The Zero-G Facility, as it's called, is booked months in advance. The reason: its concrete-lined silo creates microgravity—weightlessness—more effectively than a trip in the space shuttle. It is, in fact, microgravity as pure as can be found anywhere this side of deep space.

Indeed, space travel can be superfluous—even a hindrance—to some forms of research into the behavior of materials and living things beyond the reach of gravity. "There are a lot of diehards convinced that you can do good science in microgravity and never have to go to space," declares Jack Salzman, deputy chief for science at NASA's space experiments division at Lewis. "They get their data faster and cheaper and they can report results to their peers sooner."

Physicist Roger Crouch, chief scientist in the microgravity science and applications division at NASA's Washington headquarters, can appreciate that. "I came into the program in 1978 to run a materials-processing experiment," he says. "If we're lucky, the experiment I was approved for back then may fly in 1995." The story is a familiar one to Salzman. "An experiment aboard the shuttle takes years of prepa-

IAN ADKINS

A near-vacuum in the Zero-G Facility's shaft ensures the one-ton capsule a fall as free of resistance as possible; a styrofoam-filled barrel helps bring it to a stop.

ration and costs millions of dollars," he says. "Some of these people are *relieved* that they don't have to go to space to achieve their research goals."

If the scientists didn't have alternatives, the queue for shuttle tickets would be longer than an Earth orbit. Microgravity research has grown along with the shuttle program and NASA's dream of a manned space station: the agency's budget for microgravity studies has ballooned from $17 million in 1985 to $150 million for the current fiscal year. But progressively less of the work is directed toward solving logistical problems of living and working in space. Inspired by experiments aboard early shuttle flights, a growing number of NASA-backed researchers use gravity's absence to try to glimpse nature's basic processes.

There's more at stake than pure science, however. Engineers envision using weightless environments to grow crystals with flawless symmetry, producing more effective electronic conductors or wonder drugs than planet-based efforts could ever create. They picture deep-space factories where weight-free molecules combine to make new alloys they never could produce on Earth. "We have a whole complement of microgravity investigators whose work is being supported because of the likelihood of direct applications both in space and on Earth," says Salzman, a compact, chatty physicist given to storytelling.

A stroll through the gymnasium-size workroom next to Thompson's bay in Lewis' space experiments laboratory shows what he means. Down one aisle, a team of five engineers is assembling a barrel-size experiment to fly aboard a sounding rocket—a projectile two feet in diameter that carries payloads 55 miles above New Mexico's White Sands Missile Range and provides six or seven precious minutes of gravity relief on its way back to Earth. At the experiment's center is a tray filled with alcohol. Aloft, the alcohol will be set aflame, and the speed and pattern of burning will be recorded by the capsule's banks of probes, sensors, computers, and eight cameras. "This is basic science, but there are also implications for spacecraft fire safety," explains chief engineer Kirk Logsdon.

A few feet away, a team of technicians readies a test that will board NASA's KC-135, a converted military cargo plane based near the agency's Johnson Space Center in Houston. The airplane ferries scientists and their gear out over the Gulf of Mexico, where it flies as many as 60 parabolic arcs on each three-hour excursion. The roller-coaster trajectories can slash gravity's pull to as little as one-thousandth of its normal strength for 10 to 30 seconds at a time. The technicians' package links two compartments the size of washing machines with a horizontal tube. In the air, researchers will pump gas and liquid from the compartments into the tube to learn more about how the two forms of matter interact without gravity. "On Earth,

Under the steady eye of closed-circuit television monitors, facility manager Dennis Thompson directs the launch.

the two mix together," notes NASA fluid physicist John McQuillen. "In microgravity, the gas flows through the middle of the tube with the liquid surrounding it. From that, we'll learn something about physics, but we'll also know better how to design pumps for the next generation of spacecraft."

Nearby, a lone physicist, Alex Pline, is refining an experiment for Dennis Thompson's Zero-G Facility. The investigator hopes to discover how a film of liquid held under surface tension, the force that governs liquids in gravity's absence, can be made to flow. "If you hose down a window screen, you see water droplets filling in the spaces," says Salzman. "The droplets are held there by surface tension. If we know more about how liquids behave in that state, it can tell us something about how to move liquids when gravity isn't there to move them for us."

Many of these experiments, including McQuillen's, are working their arduous way to a flight aboard the shuttle, which, despite less-than-perfect conditions, is the only U.S. facility that can provide the uninterrupted hours of reduced gravity that some experiments require. It's a years-long process that requires every aspect of a trial be tested in a host of configurations and simulators. "Nobody goes to space until they've first done everything they can on the ground to optimize all experimental parameters," Salzman says. "We don't want to get to space and say, 'Gee, I should have used a different variable.' When something goes on the shuttle, it's got to be the best possible experiment it can."

Unfortunately, few ever get there. In the past, out of every hundred experiments jostling for a place on the orbiter, only three have gotten on. While NASA is trying to improve that ratio, there will never be room aboard for more than a fraction of deserving ideas. Even for those whose concepts do eventually achieve orbit, the results can be bitter. A chemical engineer at a government laboratory tells of a colleague who waited six years for the shuttle to carry his experiment: "The astronauts were so overworked that the one handling the experiment screwed it up. This guy waited six years, NASA spent millions of dollars building his equipment, and the test came back with no data."

In one of the cramped, bland office cubicles at Lewis, three space scientists groan in sympathy. At once envious of those whose work commands shuttle space and relieved that they rarely have to depend on it, the three savor their options.

"A flight on a sounding rocket would be nice," muses David Urban, a boyish and energetic combustion research engineer, "but one flight can cost $250,000. Besides, some of our people have been building an experiment since 1991 that's just going to fly now. You have to weigh how soon you want the data against how much you need the extra time or more room for bigger hardware that a 'drop tower' like the Zero-G Facility can't provide." According to Kurt Sacksteder, who studies combustion in sub-Earth gravities such as that of Mars and the moon, the field's growing use of computer modeling helps researchers choose which microgravity machine will be the most useful in a particular task. "We're not going to complete an entire research program in a few seconds in a drop tower, but that series of tests will tell us a lot," says the shaggy, soft-spoken physicist. "We'll get a good hint about what's going on. Then, if we need more time in microgravity, we'll go to the KC-135 or a sounding rock-

By studying combustion in microgravity, David Urban (with fellow research engineer Sandra Olson, below left) hopes to help improve fire safety standards for spacecraft. In his study of how two burning sheets of paper 10 millimeters apart influence each other, conducted in Lewis' 2.2-second drop tower, Urban found that flames in reduced gravity (right) interact more than flames in normal gravity (middle). Without gravity, hot air doesn't rise and pull in oxygen, so the flame burns spherically and is quickly snuffed out.

COURTESY DAVID URBAN

Some microgravity researchers are relieved they can achieve their goals without going into space, says Jack Salzman. Behind him is Lewis' DC-9, one of two aircraft the center devotes to microgravity research.

et." Research engineer Sandra Olson weighs those options against the protracted trail set out for those who must wait for a shuttle berth. "We've got it pretty good," she says with a sly smile.

To understand the various ways in which scientists thwart gravity, first it's necessary to understand gravity itself—not the nature of it, which makes for eye-glazing mathematical abstractions, but its practical effects. Sir Isaac Newton discovered that the Earth's gravity attracts any body with a force that is proportional to the mass of the body; that force decreases with the square of the body's distance from the center of the Earth. This force of attraction is what holds us to the ground, makes apples fall, and keeps the moon and artificial satellites in their orbits. Near the surface of the Earth, gravity causes any freely falling body to increase its speed by 32 feet per second during each second it travels. That rate of acceleration applies to all bodies regardless of their mass; a golf ball dropped down a mineshaft will accelerate just as quickly as a cannonball will once the effects of air resistance are factored out.

Gravity, in other words, is more complicated than first appearances suggest. Microgravity isn't. Put simply, microgravity is a matter of falling. To counter gravity's influence, one need only surrender to it completely.

The analogy NASA scientists like to use to explain this conundrum is that of the falling elevator. Imagine that a skyscraper's elevator has snapped its cable and is plummeting unrestrained toward the basement. Essentially, the elevator itself and everything in it are in freefall—dropping as fast as gravity can impel them. But a passenger in that elevator doesn't necessarily sense that he's falling. He feels no air rushing by him; he sees no objects flying past. If the passenger lifts his feet off the ground, he appears to hang in the air; if he's holding a briefcase and lets it go, the bag appears to hang in the air too. The reason: the passenger, his bag, and the elevator's floor are all accelerating at an identical rate.

The result nullifies gravity's effect within the elevator's confines. Gravity normally makes itself apparent as a difference in weight between objects. But because gravity is affecting all things in the elevator to its limit, all objects within the elevator essentially end up having the same weight.

The same effect defines the "weightlessness" astronauts experience in space. If the space shuttle could stop moving and hover motionless in orbit, those aboard would feel a full 95 percent of the gravity they feel on Earth. The shuttle's cargo is made to seem weightless because, as in the example of the elevator, it's falling with the same acceleration as the spacecraft itself—held in an arc that parallels the curvature of the planet by a balance between the force of gravity and the centrifugal force due to the curvature of the orbit.

Counteracting gravity on Earth, then, is only a matter of creating the best conditions in which to fall. But "best" is a relative term. Sacksteder explains: "Drop towers give you the best-quality Gs around—down to a millionth of normal gravity—but it only lasts a few seconds. In the sounding rocket or on the airplane, you get more time but lower-quality microgravity. That's the kind of trade-off involved in everything we do."

It's enough to give scientists a case of the jitters—literally. While sounding rockets and parabolic airplane flights extend each weight-free interval, they also bring on the "G-jitters." The subtle throb of a pump or *thrum* of an engine can set off tiny vibrations that ripple through the vehicle's structure or internal atmosphere. The jitters can pummel a freefalling experiment, disrupt its communion with gravity's steady pull, and bar the payload from entering subtler levels of reduced gravity—below a thousandth of normal. Even the space shuttle, enticing researchers with its days of uninterrupted weightlessness, is a flying case of the shakes. For the shuttle to afford an experiment the same degree of jitter-free microgravity that a drop tower provides, the ship's

crew would have to sit motionless, with the experiment's module positioned precisely at the shuttle's center of gravity. Even an astronaut floating by can give a delicate experiment palpitations.

No wonder David Urban wants to do his homework in the drop towers before going into space. Even planning his Earthbound studies of the ways in which two adjacent flaming sheets of paper influence the way each other burns—work that presently falls in the "pure science" category but may someday have applications in spacecraft fire safety—Urban found that the limitations of each microgravity machine were as integral to his calculations as were the chemical equations.

His first step was to take his idea to Lewis' 2.2-second drop tower—a converted 100-foot fuel distillation tower dangling from a bluff over the Rocky River at the campus' northern rim. Twelve times every weekday, tower manager Jack Lekan and his crew hoist one of the facility's two- by three-foot payload chambers to the ceiling, where the pod hangs from a piano wire. At the flip of a switch, a horizontal piston resembling a chisel pops out of a housing and snips the wire. The capsule then falls 88 feet into an airbag 12 feet deep.

Among the tower's three dozen well-used payload pods, Urban was able to find one already configured to his needs: a breadbox-size compartment in which to hang the two sheets of paper, a bare electric wire to ignite them, and a video camera to record the results. Such a simple test can be rigged and ready to fall in an hour or two. "Almost every line of experiment starts here just because the hardware is the easiest to build and the access is regular," Sacksteder says.

Urban and his colleagues assemble their experiments in a jumbled workroom adjacent to the tower, aided by the station's four technicians and three engineers. Sitting amid the clutter of lab benches, tools, parts, and metal payload frames in various stages of assembly, Lekan explains why business is so brisk. "In other facilities, usually you have to wait months while technicians build your equipment," says the lanky engineer. "Here, we've made more than 12,000 drops since 1959. With the 36 payload frames rigged with various configurations of computers, cameras, and measuring devices, people can usually find something suitable. All they have to do is plug in their specific components." There's another reason: the shaft is "quiescent," or jitter-free.

Urban likes the combination. "When you need to make a lot of measurements, the quiescent environment is best," he says. "Also, someone with a hot idea can build an experiment and test it in the small tower in a matter of days. After you analyze your results and refine your experiment, you don't have to wait long for another drop. If someone's equipment isn't quite ready you can grab their slot in the schedule or you can barter." Eager scientists such as Urban have turned Friday afternoons at the tower, when the week's drops are scheduled, into a sort of auction. "People are milling around saying, 'Who'll give me a slot on Tuesday afternoon for a Thursday at 2:30?' " Lekan chuckles. "We've had to make a rule that no person can have more than two drops in a single day."

Jack Lekan, manager of the 2.2-second drop tower, and technician Marlon Richmond (bottom) make final preparations for a payload drop.

NASA's KC-135 provides another microgravity route. In one experiment aboard the aircraft, fluid physicist John McQuillen pumped fast-moving air and slower-moving water into a tube. In normal gravity, the gas tends to flow at the top of the tube, with the water at the bottom (below left; top photo). But under the same conditions in reduced gravity, the gas pushes the water out of the way, creating a core of air surrounded by water (bottom). Such research may lead to improved environmental control systems and fuel pumps in space.

COURTESY JOHN MCQUILLEN

Eventually, most experiments outgrow Lekan's stubby chute. When Urban's did, he considered moving his tests to Thompson's five-second gravity void. But scientists can wait more than a year while the tower's five technicians equip one of the facility's six two- by eight-foot payload kiosks with a customized assemblage of gear. Ironically, the dropping procedure itself further slows research. Before each drop, Thompson and his technicians spend 45 minutes emptying the chamber of most of its air in order to diminish air resistance. After a payload falls, a crew must descend to the pit floor and vacuum up the spewed styrofoam. To remove the pod, the tower's massive lid must be unbolted and moved aside by a 20-ton crane. Even operating at a breakneck pace, the tower can manage no more than two drops a day; a more typical rate is four drops a week. As a result, demand for a few of the 80-odd seconds of microgravity the tower provides each month is so fierce that few experiments are granted more than 12 or 15 drops in total, and the duration between each can stretch longer than some researchers are willing to wait.

In Urban's case, his experiment relieved him of the choice: he found that to learn more he needed to let his sheets of paper burn longer than just a few seconds. So he mounted a larger version of his test on a five-foot rack fitted with gas bottles to control the experiment's airflow and volume and took the rig aboard Lewis' Learjet, donated by the Internal Revenue Service, which had confiscated it from an alleged drug runner. The jet can carry no more than three researchers, huddled around a lone experiment, through sharp arcs that shrink Earth's gravity by a hundredfold for as long as 20 seconds—more time than the drop towers, but with a poorer quality of microgravity. The jet is also limited in the number of arcs it can fly because each one increases the engines' oil use: more than six in succession could destroy them.

To conduct more tests per flight, he, along with a squad of other microgravity scientists, traveled to Houston's Ellington Air Force Base and a rendezvous with the KC-135. Loaded with a dozen or more experiments and technicians, the aircraft climbs at a 45-degree angle from about 25,000 feet to 37,000 feet and enters a parabolic arc: as it rounds the top of its trajectory, the airplane proceeds to fall out of the sky at a 45-degree angle. For anywhere from 10 to 30 seconds, depending on wind and weather, anything in the airplane's thickly padded cargo hold becomes weightless. (Often an investigator's breakfast also becomes free-floating, earning the airplane the nickname "Vomit Comet.")

Experiments like Urban's, bolted to the cabin floor, find gravity reduced to about one-hundredth that of normal; those allowed to float free skirt the jitters imparted by the airplane's frame and cut gravity's pull by another order of magnitude. But a floating package, says Sacksteder, usually bumps into the airplane wall or ceiling after seven or eight seconds, so scientists don't get that much more time than they do in a drop tower. "If you're patient and do the experiment over and over again, every once in a while you get a real good session," he adds. "I've had some float for as long as 12 seconds."

Such interludes are rare. "On the airplane, results are less predictable than in the drop towers," Urban reports. An accelerometer, which measures gravity levels, is attached to each experiment and signals the degree of weightlessness each parabola achieves. "There's a lot of analysis," Urban adds. "You sift through all the runs and say, 'This one was good' or 'This one was a waste of time because we hit an air pocket.' "

Still, most scientists are willing to take those chances to gain the advantages that ground-based microgravity machines provide. "In some areas of research, such as crystal growth, there's very little that people can do on the ground," Sacksteder says with a touch of pity. "So they spend big chunks of their careers planning for this one big moment when they have an experiment aboard the shuttle, and maybe they get data and maybe they don't. We're very fortunate that we can get a lot of hints, and in most cases do honest-to-goodness, closed-end science, from ground facilities."

A faraway look enters David Urban's eye. "Yeah," he says, glancing skyward, "but I doubt there's a day that goes by when we don't say, *Gee, if only...*"

Weightlessness on a Table Top

Steve Gonda looks raptly at a tiny device whirring atop a lab bench in Building 37 at NASA's Johnson Space Center south of Houston. A small cylinder is enclosed in a double-walled larger one, and both rotate synchronously on a horizontal axle protruding from a small plate. The assembly is attached to a base holding a motor that looks like it was borrowed from an Erector set.

The machine, called a rotating wall bioreactor, is ingeniously simple in concept. The space between the two cylinders is filled entirely with a viscous growth medium, squeezing out all air. Suspended in the medium are living cells. With no space for the medium to slosh or shift, the cells are held nearly motionless within it as they rotate around the central axis.

The bioreactor doesn't create microgravity but it does simulate key aspects of it. As the cylinders turn, gravity causes the cells encased in the medium to shift very slightly from their original positions. "The cells are in freefall," explains Gonda, Johnson's chief biotechnology scientist. "We balance that freefall with the rotation speed of the axis, so the cells are held in a nearly constant position. It's like being in Earth orbit." It also brings the same result. "The cells perceive gravity as coming from all directions in the course of one rotation," he says. "In effect, gravity is zeroed out."

In traditional culture devices, where gravity can restrict sensitive cell-to-cell interactions, most cells grow as two-dimensional sheets. But, for reasons not fully understood, the space-like, quiescent fluid environment of the rotating wall bioreactor allows cells grown there to continuously interact much like they do in the body, making three-dimensional growth the rule. Since most cells grow and function as three-dimensional tissues and organs in our body, the ability to grow three-dimensional, tissue-like cell aggregates in the bioreactor has great promise.

Since developing this technology, NASA has made it available to the scientific

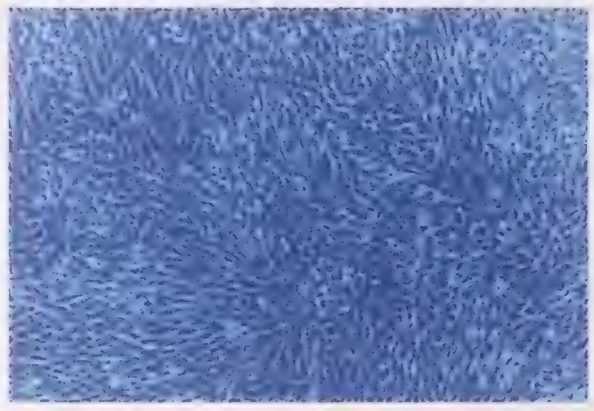
community. Investigators are using it to study cancers such as breast, prostate, and colon, as well as normal tissue such as pancreas, bone, and cardiac and skeletal muscle. They are growing three-dimensional muscle in bioreactors to understand normal muscle growth and development, as well as the prevention and reversal of muscle atrophy due to prolonged bedrest, immobilization related to injury and disease, and spaceflight.

Gonda himself is trying to learn why bone doesn't always bond well to surgically implanted titanium prostheses. "We can put titanium together with bone cells and watch the cells grow into it," he says. "Then we can begin to answer a range of questions without the use of animals as experimental models: What extracellular materials does the bone secrete to form that bond? Is a rough or smooth titanium surface most effective?" Also, the bioreactor's spin speed can be raised to see if mild force aids or hinders the bonding between bone and metal.

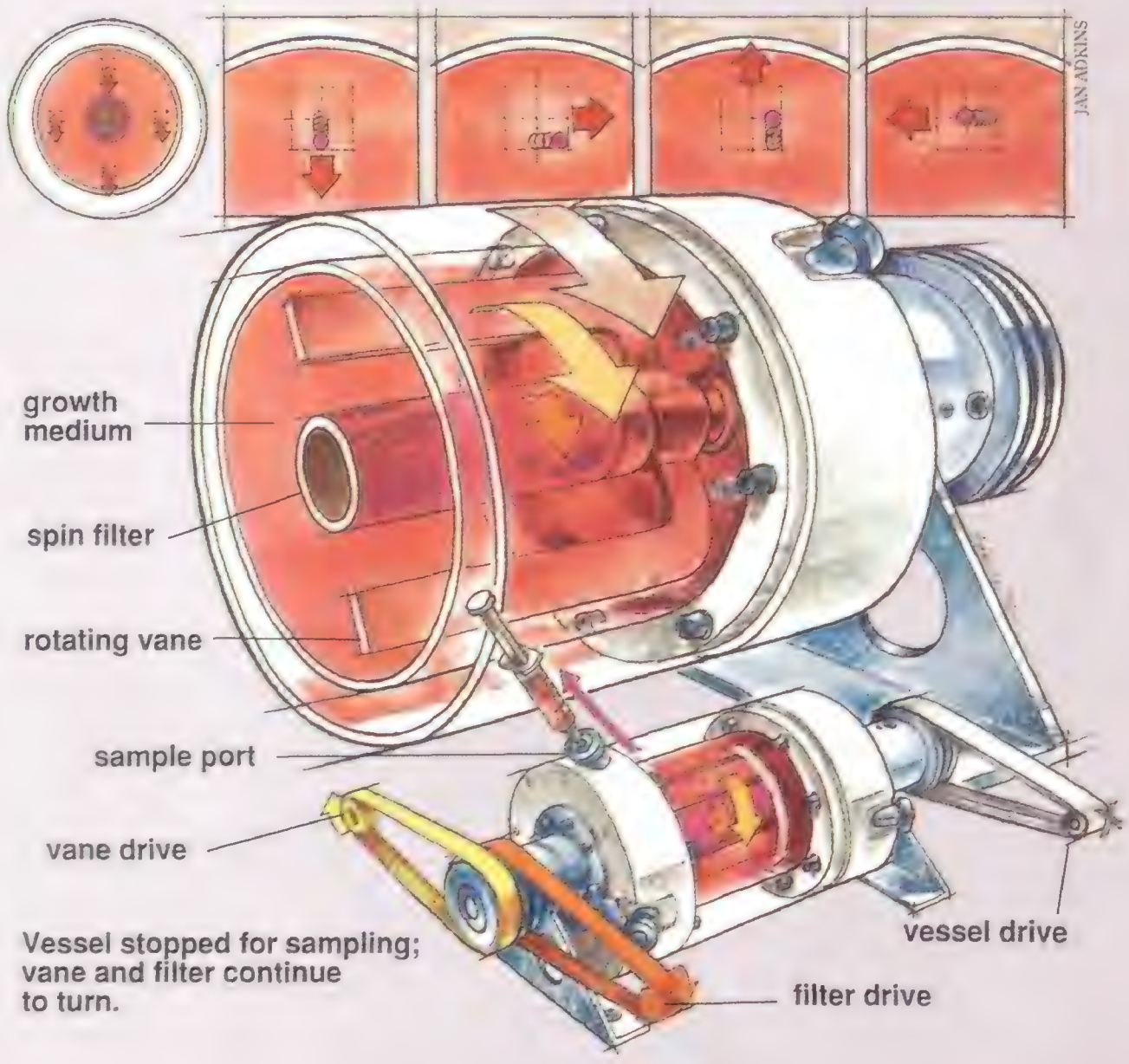
In other tests, one biologist placed colon cancer cells in the bioreactor and watched them grow and differentiate into the five distinct cell types found in a fully developed colon. Another enclosed heart cells in the device. After several days, he found the cells had grown together to form rhythmically contracting three-dimensional heart tissue. Adds Gonda: "You won't see that in a Petri dish."

But gravity is still imposing limitations on the science. As the cell clusters grow larger, the medium must be rotated faster to hold them in place. But when they grow beyond a centimeter in diameter, the vessel cannot be rotated any faster. Beyond a certain rate, rotation propels the large aggregates out of suspension and into the bioreactor's outer wall, often destroying the delicate three-dimensional tissue structure. Scientists hope they'll be able to achieve more growth by operating a space version of the bioreactor on the shuttle. Three flights are scheduled for the hardware, the first in June 1995. In the microgravity environment of space, rotation of the cells will no longer be necessary, giving them an even more stable environment. Says Gonda, "These scientists are counting on NASA's space bioreactor to finally overcome Earth's gravity limitations."

NASA/JSC



Because gravity pulls on cells in NASA's rotating wall bioreactor from ever-changing directions (see boxes, below), it effectively becomes nullified, allowing large and small cell clusters to co-locate and interact much as they do in the body. Cell biologist Garry Marley used the bioreactor to culture human glioma cells. The result (above right) resembles the dispersal of cells found in an actual brain tumor, with the cells assuming different shapes depending on their immediate environment. Cells from the same line grown in a conventional two-dimensional culture (above left) show none of this differentiation. (Different stains have been used to enhance different cell features.) This research has the potential to help the development of cancer therapies by providing living human tissue for research. Since rotation is such a vital part of the equation, the machine is designed to keep the growth medium in motion even when the outer body is stopped (bottom).



JAN ADKINS

The Race to Save Rwanda

Thousands of lives depended on running a supply line through Rwanda's capital and reopening an airport crippled by war.

by Stephen F. Vogel

Photographs by Klaus Reisinger/Black Star

From the air, the U.S. Air Force C-5 parked on the tarmac at Rwanda's Kigali airport seemed to dwarf the terminal, like a great shark washed ashore next to a sand castle. This was where, four months earlier, all the madness had begun. An airplane carrying the presidents of Rwanda and Burundi took off from Kigali airport on April 6, 1994. Only seconds later it was shot down by a rocket, triggering the genocide and reigniting the ferocious Rwandan civil war, which raged around the airport and in the nearby capital until just weeks before the Americans arrived. By the end of the slaughter, 500,000 people had died, mostly members of the minority Tutsi tribe, killed by the Hutu majority.

The airport looked like it had been through a war. Huge chunks of concrete lay amid shattered yellow directional signs and other rubble left from the blasts by mortar rounds. Broken glass and sandbags were strewn inside the three-story terminal building, an ugly, Third World Modern structure with lots of concrete buttresses and lots of what had once been windows. On this Sunday morning, July 31, passenger check-in counters were deserted; customs and immigration stations, empty. There were no airport employees. If they hadn't been killed (trained workers were among those the Hutus targeted in their campaign to extinguish the Tutsis), they had fled to refugee camps or vanished into the forests. The only presence greeting the U.S. military personnel gathering in the terminal was a stuffed mountain gorilla, Rwanda's previous claim to fame, whose glass eyes stared from a window display case.

Until the U.S. Air Force arrived, the control tower at Kigali was manned by a lone U.N. officer—a lieutenant colonel from Bangladesh—whose equipment consisted of one radio and one altimeter.

A single Air Force Mobility Command C-5 (opposite, bottom) brought everything needed to open the airport to 24-hour operations. Thereafter, tons of supplies, like the plastic sheeting for shelters flown in on a Ukrainian An-124, were unloaded at Kigali and trucked to Zaire.

"Welcome to Kigali," said U.S. Air Force Lieutenant Colonel Ron Peck. The senior U.S. officer on the scene, Peck cautioned the soldiers to stay on paved areas since countless unexploded mortar shells and mines had been left from the fighting. Then he dismissed them to begin their mission: restore the mangled Kigali airport to 24-hour operation.

Kigali was not the most critical destination for the international humanitarian relief operation planned for Rwanda. Initially the hundreds of tons of food, medical supplies, and equipment coming from around the world were headed toward the Zairian border town of Goma, where most of the refugees had fled. But the commanders of the U.S. military's Rwandan relief task force quickly realized that any large-scale relief operation would need the Kigali airport.

The U.S. relief force, set up on July 22 at the Entebbe airport in Rwanda's northern neighbor Uganda, grew to 800 soldiers and airmen. The handful of C-5s already flying into Uganda were draining Entebbe's fuel supplies, which also had to serve commercial airliners, and were creating nightmarish parking problems. Goma's airfield was far too small and was controlled by the French army, which needed most of the space for its relief operations. Aircraft were being routinely diverted from Goma because of congestion on the ground, where a shortage of cargo handlers kept the ramp clogged. One afternoon, a U.S. Air Force C-141 carrying desperately needed rehydration tablets circled Goma for hours before diminishing fuel forced it to land in Mombasa, an Indian Ocean port that was

often the *starting* point in the supply line.

Another U.S. motive for opening the airport in Kigali was the hope that a network of food, water, and medicine stations could be set up in Rwanda to encourage the refugees to come home and to assist them on their journeys. Upwards of one million people, primarily Hutus, had fled to Goma, where they were dying of cholera, dysentery, and other diseases at a rate of about 2,000 a day. "Clearly the way we end this catastrophe is to get people to go home," said Army Colonel Daniel Layton, director of the state department's Office for International Security and Peacekeeping Operations. But the camps remained full. As 1994 neared an end, hundreds of thousands of Rwandans, afraid of retribution should they return, stayed in Zaire.

"This airfield is better than Entebbe," Peck

told members of the task force who evaluated Kigali during the last week in July. Kigali's runway is 11,483 feet long, 1,483 feet longer than that at Peck's home base, McGuire Air Force Base in New Jersey. "For an African airfield, it was excellent," Peck said later. "Eleven thousand feet is a great runway." Here and there the runway was pockmarked from mortar shells, but it was usable. The ramp, however, had to be cleared of shrapnel. Peck told the U.S. troops that the priority was "to get command and control up and establish operations on the ramp."

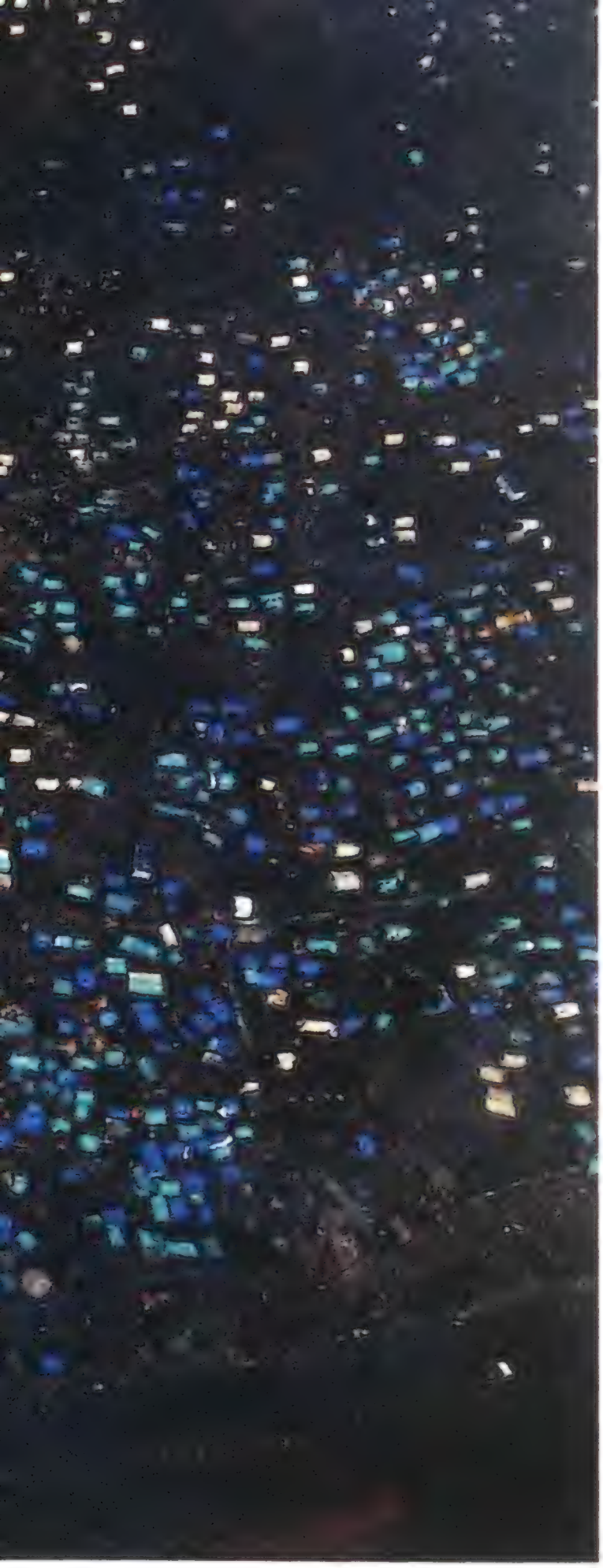
For situations like this, the Air Force has devised a handy, all-purpose airport-opening kit, which the service calls a Tanker Airlift Control Element. The TALCE is a pre-fab, rapid-deployment command and control center, a package of equipment and

personnel able to provide—even under combat conditions—communications, aerial port services, weather information, and intelligence. The equipment comes with a cadre of about 16 people to operate it, augmented where needed by teams with specialized skills in aircraft maintenance, cargo handling, security, and combat air control.

"We have the capability to go out into a bare-base environment [and] control movement and handling of aircraft on the ground," said Lieutenant Colonel Jim Bozard, a TALCE commander. "We can respond in 12 hours and go anywhere in the

In Zaire, more than a million refugees suffered in squalid camps. By opening Kigali airport, the U.S. task force hoped to improve conditions in Rwanda and help the refugees return.

Airport restrictions were not enforced in Goma. French and U.S. troops jogged by Rwandan refugees strolling along the runway.



A British-owned helicopter transported heavy plastic tubing used to set up a water supply system at the Goma camps.

world. We're very mobile. Our gear and everything we need, from uniforms to weapons, is kept ready to go."

The U.S. Air Force Air Mobility Command, headquartered at Scott Air Force Base in Illinois, has over a dozen TALCEs at its disposal, and their recent assignments reflect the extent to which the Air Force relies on them. There is a TALCE in Split, Croatia, assisting in the humanitarian airlift to Bosnia. Another had been in Totskoye, Russia, during September, participating in the first joint U.S.-Russian land training exercise. One was flown into Port-au-Prince aboard a C-5 on September 19, the first day of the U.S. intervention in Haiti. Another is in Guantánamo Bay, Cuba.

Minutes after Peck's welcoming remarks, part of a 54-person team from the 436th Air Lift Wing at Dover Air Force Base in Delaware was unloading from the C-5 the cornerstone of any TALCE, a Mobility Air Reporting and Communications shelter, or MARC. The size of a mobile home, a MARC is a trailer packed with communications equipment—VHF and UHF radios, satellite phones, secure faxes, and computers. Fully loaded, it weighs about 18,000 pounds. With well-practiced ease, a team moved the MARC into position on the edge of the tarmac close to the terminal. Communication

Seeking shelter, a Rwandan woman settles her children near the Goma airport VOR navigational antenna.

specialists soon had the equipment inside humming, and the TALCE team was now prepared to accept the flow of relief aircraft, track the status of resources, and manage passenger and cargo operations.

The next step was to restore electricity and water to the airport. The MARC came

with its own generator, but another source of power would be needed to get the runway lights turned on. Engineers worked to repair airport generators and water mains in the city while another group worked to unload forklifts, all-terrain vehicles, generators, and fuel bladders from the C-5. Within four hours of their arrival, the troops had operations at the airport up and running.

Two weeks later, the airport, staffed by the TALCE crew, 26 cargo handlers, 28 maintenance personnel, 24 fire and emergency crewmen, and 16 civil engineers from bases across the United States and Europe, was buzzing with activity. On one afternoon, enough aircraft were scattered across the tarmac in Kigali to field an international airshow. At one end was a Ukrainian Antonov An-124, two U.S. Air Force C-5s, a U.S. Air Force C-141, a German Transall 160, a Belgian C-130, and a Czech Boeing 707.

Unfortunately, only three of the aircraft

had been scheduled to arrive during that time. Inside the MARC, Captain Rich Keys, one of the controllers, was directing aircraft into positions for unloading.

"Today's about the worst we've had with unexpected drop-ins and delays," said Keys.

"All of a sudden you've got four other players, and it becomes a challenge to make sure you safely integrate them into the parking plan," Bozard added.

The international nature of the airlift required the Air Force team to become rapidly expert in handling a variety of unfamiliar aircraft. The TALCE crew scrambled to get the arriving aircraft parked and out of the way to make room for more. A C-141 was kept circling overhead for about half an hour while the ground personnel raced to unload aircraft and clear space.

"We've had the ramp saturated numerous times. You couldn't fit a marble in," said Bozard. "We have yet to divert an airplane."

By August 19, 415 aircraft carrying 5,132 passengers and 3,068 tons of equipment and relief supplies had landed in Kigali. "We've had just about everything you can imagine come through here, from cranes to beans to flour to medical supplies," said Bozard. "You name it, it's probably been through here. Tarps, water bottles, porta-potties—everything it takes to keep people alive."

Children from the camps helped French soldiers repair runway lights—and covered their ears when the An-124s took off (left).

It was in fact far busier than the Kigali airport ever had been in the days before Rwanda blew up. "The Rwandans said they were busy with four aircraft a day. Six was the worst-case scenario," said Major Dennis Steide, the officer in charge of the Canadian airfield support detachment working in the control tower. During the airlift it was not unusual for 15 aircraft to come through in a four-hour period.

By mid-August, U.S. commanders were already planning to withdraw, and the American presence at the airport slowly began to drop. More and more Rwandans were being trained to take over airport services, such as firefighting. Passenger service representatives-in-training got to practice by booking relief workers and reporters onto U.N. flights out of Kigali. A team from the U.S. Federal Aviation Administration visited Kigali during the third week of August to recertify the airport for commercial traffic, and in September, when Belgian carrier Sabena landed, commercial airline service to Kigali was under way once again.

Commercial traffic has resumed to Kigali, but the country's own airline was still grounded as this magazine went to press.

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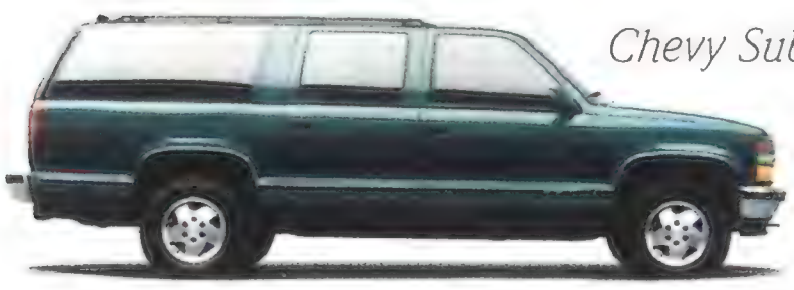

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THE X-HUNTERS

Two aviation buffs are tracking down the forgotten history of America's most revolutionary aircraft.

by Lance Thompson

Photographs by Chad Slattery

Tony Moore (above left) and Pete Merlin can take off across daunting stretches of faceless desert and turn up the tiniest scraps of airplane debris. Among their most recent finds: the fuel tank pressure gauge from the X-1A (opposite), once the fastest aircraft in the world.

August 8, 1955: A B-29 is flying 31,000 feet above Edwards Air Force Base in California, carrying in its bomb bay the fastest aircraft built to date, the rocket-powered X-1A. Test pilot Joe Walker sits at the controls of the rocket plane, ready to take off.

The risks Walker faces are grave. Mysterious explosions have destroyed two previous experimental aircraft in the bomb bays of their motherships prior to launch—the X-1D in 1951 and an X-2 in 1953. Later analysis will show that the Ulmer leather gaskets in these aircraft were impregnated with a chemical called tricresyl phosphate; when this chemical comes in contact with a rocket plane's liquid oxygen, a compound is produced that is easily detonated when subjected to shocks. As it happens, the liquid-oxygen tanks in Walker's X-1A are also fitted with Ulmer leather gaskets.

Less than a minute before launch, an explosion rocks the X-1A, rupturing its liquid-oxygen tank, ripping out the center section access panels, and blowing open the landing gear doors.

Air Force major Arthur Murray, flying chase in an F-86, observes a tongue of flame and a trail of white vapor emanating from the damaged rocket plane. He advises B-29 pilot Stanley Butchart to maintain speed so that if the X-1A comes loose, Walker will have a chance to glide to a landing. But his principal advice is to Walker himself: "Joe, old boy, get out of that thing right now and get up in the bomb bay."

Though they don't know how firmly

the X-1A is attached to the mothership or whether it is on the verge of exploding, crewmen John Moise and Charles Littleton each set one foot on the bomb bay floor and one on the X-1A and help lift Walker out of the rocket plane to safety.

The pilots and crew want to bring the X-plane back intact, but its landing gear now extends below that of the B-29, so the mothership can't land without crushing the gear of the smaller plane. That could set off another explosion.

They decide they will have to jettison the X-1A after all. Over a remote section of the base bombing range, they release the unmanned aircraft, which spirals down in a flat spin and explodes on impact.

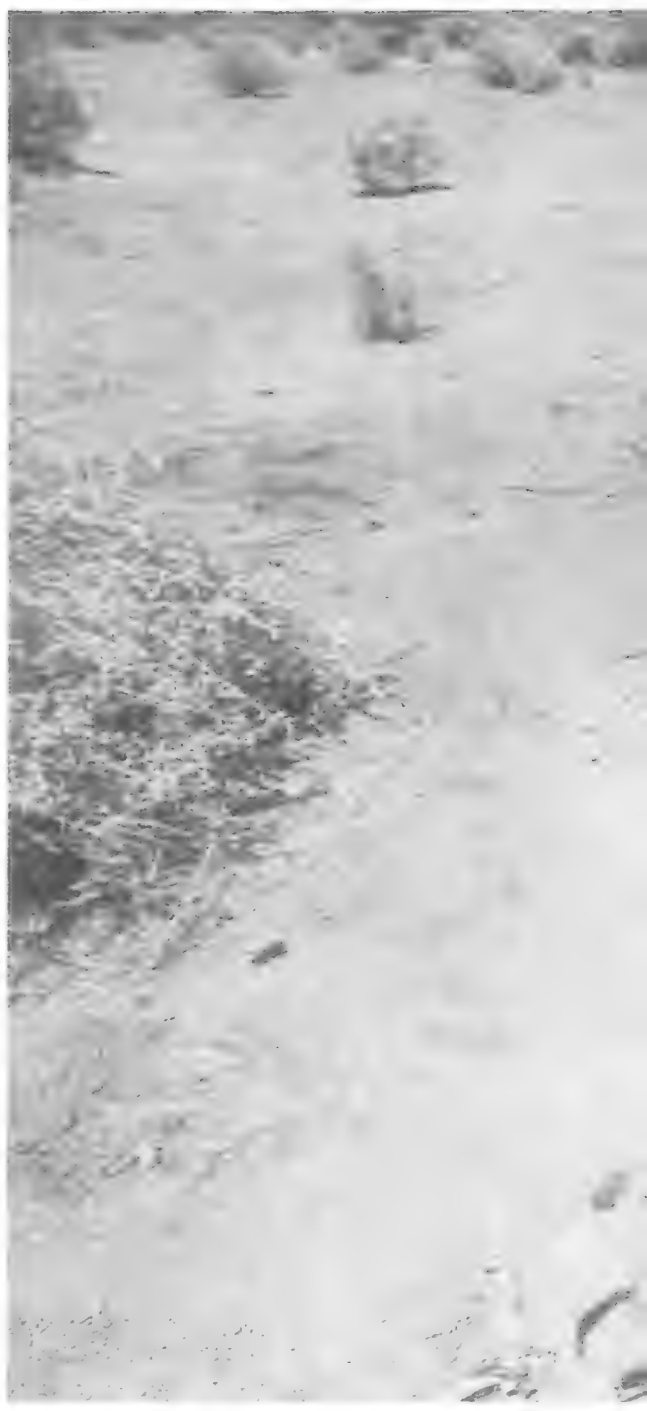
A few hours later, recovery crews arrive and set to work surveying the site and photographing the wreckage. The next day, Air Force personnel load the large pieces onto trucks and take them back to the base for study. The rest of the pieces are left scattered among the Joshua trees of the California desert, where they will lie, unnoticed, for almost 40 years.

Countless experimental aircraft from the flight test center at Edwards have ended up in smoking holes in the Mojave Desert, often taking pilots and crewmen with them. Among the fallen are two Northrop flying wings—the wooden N9M in 1943 and the larger YB-49 in 1948; an X-2 in 1956; the NF-104, from which Chuck Yeager barely managed to escape before its 1963 crash; an X-15 that broke up at Mach 5 in 1967; and the XB-70 experimental strategic bomber, which collided with an F-104 in 1966. In the immediate aftermath of accidents like these, the program officers focus on recovering the bodies, carting away the bulk of the wreckage, and identifying the cause of the accident. The investigations are careful but not always exhaustive: small pieces of wreckage may be left behind, for example, and the precise site of the impact may go unmapped.

But in 1991, two aviation buffs named Tony Moore and Pete Merlin began filling in those gaps in the historic record. During repeated expeditions through the vast Mojave, the pair has discovered the crash sites of each of the aircraft mentioned above. And with each trip, Moore and Merlin add a little more to the history of flight testing at Edwards. "We don't do accident investigation," explains Merlin. "We're not coming up with any new theories. What we do is locate the site, identify the artifacts, and bring them back for others to see them."

They specialize in experimental aircraft that flew from 1940 to 1970, and no place on earth offers the concentration of experimental aviation history found in the Antelope Valley, the stretch of desert that includes Edwards. This is where the most advanced aircraft in the world are tested, some beyond their limits. "Living this close to Edwards is like an archeologist living in Egypt," says Moore. Merlin agrees: "This is the Valley of the Kings."

Moore, hearty and gregarious, is a T-shirt and jeans guy who loves to talk airplanes over a beer. He grew up in the San Fernando Valley, under the sonic booms of Edwards X-craft. Moore



Above: At the X-1A crash site, Merlin methodically documents the artifacts he and Moore have discovered, which include (below, left to right) the faded face of an altimeter, an airspeed indicator, and a clock.

got his start as a wreck chaser one day in 1991, while shopping at a pilot supply store in Lancaster, California. The store's owner, Tom Rosquin, had tacked up a photo of himself with wreckage of the XB-70, which he had located a few years earlier. Staring at the photo, Moore grew determined to go to the site himself and search for more wreckage. It took several trips, but he eventually found parts of the XB-70's body and engine. "When Tony came back with pieces," recalls Rosquin, "he went ballistic for finding crashes."

Moore's partner, Pete Merlin, is reserved and meticulous, with a bachelor's degree from Florida's renowned Embry-Riddle Aeronautical University and a background in amateur archeology. Kim MacDonald, a pilot who runs an aviation-theme bar near Edwards, characterizes the pair this way: "If you've got a question, Pete's got the answer. But it takes him a little while to warm up. Tony's the PR guy—he'll talk to anybody."

Both men work at the Burbank, California airport, Moore as a ground crew member, Merlin as a station agent. They discovered they were both interested in aviation archeology during a casual conversation four years ago, and ever since, they've been hunting crash sites together in their spare time.

The pair's greatest success so far has been their July 1992 discovery of the crash site of the third X-15, near Johannesburg, California. As Moore sets the accident scene, a feeling of awe creeps into his voice. "That plane didn't hit the ground—it came apart in the air, going 3,000 miles per hour at 65,000 feet. The X-15 was built like a tank, out of a nickel-steel alloy, and turbulent air shredded it like paper. The test pilots knew that could happen, but they kept going back up there. That's why these guys are my heroes." Merlin continues: "The wreckage was spread over 20 square miles, but we found the largest pieces we ever recovered—an engine access panel, a reaction control rocket

Moore and Merlin donate their finds to Edwards' Flight Test Museum, where curator Doug Nelson marvels at the pair's crack detective skills.

for maneuvering in the upper atmosphere, a piece of the horizontal stabilizer, and a section of vertical stabilizer that had the numerals '72' on it. The tail number of the third X-15 was 66672."

Such luck is rare; more often Moore and Merlin have to verify their finds by locating serial numbers, part numbers, and manufacturer inspection stamps on pieces as small as a half-dollar. They can also verify an artifact by studying a detailed photograph of the aircraft, or by identifying a particular construction material or paint. In the case of the N9M flying wing, a bright yellow wooden aircraft, Moore and Merlin tracked down the crash site from a grainy 50-year-old photograph, and when they went out to investigate, they found a rudder hinge and pieces of wood with bright yellow paint.

Moore and Merlin donate almost all of the artifacts they find to the Air Force Flight Test Center Museum at Edwards. "As cool as it would be to have these things at home," Merlin says, "this is where they belong." Museum curator Doug Nelson is grateful for the archeologists' tenacity. "If it came from Edwards," he says, "they're the guys to talk to. They very seldom come back empty-handed."

At the site where one of the legendary X-15s crashed, Moore and Merlin found the biggest artifacts they've bagged yet. Above, they show pieces of the rocket plane, a replica of which is displayed behind them. Another X-15 remnant, a piece of the craft's skin (right), is displayed on the wall of Wing and a Prayer, a local pub where the pair are well known (opposite, bottom).

November 1992: Moore and Merlin decide to locate the crash site of the X-1A. Merlin is optimistic: "Cheryl [Gumm] in the history office told us that they cleaned that site up long ago. We've heard that on every trip, and we always find something." Still, a decades-long rain of bombs, bullets, and rockets, not to mention storms, wind, and dust, may have obscured or obliterated any of the small pieces that were left. This will be Moore and Merlin's most challenging expedition yet.

They begin their search for the X-1A where they begin all their searches—the library. They pore over books, magazines, newspaper accounts, Air Force crash reports, and witness statements. Sometimes their research extends to interviews with witnesses and participants. To locate the X-15 remnants, for example, Moore called Edwards test pilot Milt Thompson, who provided a map that led the pair to the site.

From radio transcripts and crew statements, Moore and Merlin learn that the X-1A hit the bombing range near a target designated PB-3. But there's a problem: a map of the B-29 mothership's flight path points to a different area of the bombing range.

Later, while visiting the base's history office, they notice an old aerial photo of the bombing range, with one target marked in grease pencil "PB-3." But it's not the PB-3 on the current map. They conclude that the targets have been renumbered since the accident. The old PB-3 is in line with the B-29's flight path, so they are able to narrow their search to a few square miles of desert.

The site now appears to be on the portion of the bombing range under the jurisdiction of the Phillips Laboratory, a research and development complex involved with rockets, missiles, and space technology. It is one of the most sensitive areas of the base, and access is extremely limited.

To conduct their search, they must submit a detailed proposal to the Air Force and obtain an exhausting series

Only when Moore found two telltale pieces of battery casing was he convinced that the pair had found the crash site of the X-1A.

of approvals. Previous expeditions on public lands have required several trips to locate a site; this time, they will be lucky to obtain permission for one visit, lasting at most a few hours. Curator Doug Nelson gladly approves the X-1A expedition, but Moore and Merlin must also get the go-ahead from Phillips lab public affairs director Ranney Adams, Colonel Richard Poch, director of the Phillips facility's Operations and Support Directorate, base historian James Young, and historic preservation officer Richard Norwood. Norwood, for one, is in their corner: "Positively identifying a crash site as that of an X-plane, rather than a target drone or a more

common aircraft, is a significant achievement," he says. "Every discovery adds to the historical record and database. And, since these are very rare aircraft, there's always the chance they will recover a component that may be useful in a restoration."

The authorization process takes a year. Moore and Merlin use the time for further research. The X-1A's final flight was a mission for the National Advisory Committee for Aeronautics, the forerunner of NASA, so Moore and Merlin contact Joy Nordberg in the NASA Image Technology Branch at Edwards. Luckily, she turns out to have what they need. For the first time, they will have multiple photos of a crash site, which they can use on the expedition to identify key features of the terrain.

Finally, they receive permission to mount the search. Over a year of preparation comes down to one day, June 10—a few hours to search the desert for what may be only a few scraps of old metal.

At 8:00 on the morning of the expedition, public affairs officer Ranney Adams, who will escort the pair, brings them to a lecture about safety on the bombing range. They are warned about rattlesnakes, black widows, unexploded munitions, and "stuff that looks like foam rubber. Don't touch it—it's unexpended solid rocket fuel, and in rare instances it can explode when stepped on." Adams will radio their position back to base at regular intervals. They are instructed to carry water, since the heat will be scorching.

They set off from the old PB-3 site, through a flat, desolate landscape of tumbleweeds, mesquite, and Joshua trees. The Mojave sun beats down from a cloudless sky, and there's not a single breeze to offer relief—the temperature will soon reach 100. A dry creek bed runs through the terrain, and the baked soil is seared in spots by past explosions.

Moore and Merlin pass the giant steel-and-concrete slabs that cover the underground silos from which the first Minuteman missiles were tested. The bombing range is littered with remnants of cable, rusted shell fragments, pieces of bomb casings, and spent cartridges of all calibers. The metal-rich environment would have a metal detector's needle pinned at the red line, and that's one reason Moore and Merlin don't use one. "I have two metal detectors—one on each side of my nose," Moore says. Merlin agrees: "It's the experienced eye. Aircraft metal looks like nothing else you see in the desert."

During the X-1A expedition, Moore and Merlin had to endure scorching heat and dodge the occasional rattlesnake.

The X-hunters each carry what they call "the world's fastest keychain"—a collection of parts from every X-plane crash site they've located.

They crawl under a barbed wire fence with "RESTRICTED AREA" signs posted on both sides. Merlin plots their course with a battered military compass. "This is from the crash of an F-4D in the mountains of Nevada," he says proudly. "It still works."

After half an hour of scouring the desert, the terrain features begin to match the ones in the old NASA photographs—a notch in a ridge line three miles away, a Joshua tree that hasn't changed in 40 years, a weatherbeaten, sun-bleached fence post that back in 1955 was a weatherbeaten, sun-bleached fence post.

They spot the first pieces of metal—free of rust, because they're aluminum, and encrusted with white paint. The X-1A had aluminum skin, parts of which were painted white. The artifacts, at most a few inches long, would be invisible to anyone more than a few yards away.

The hardy desert scrub brush provides the only shade, and the search dislodges a Mojave green rattlesnake that was taking advantage of it. It has the most toxic venom of all North American rattlesnakes, something the archeologists have to keep in mind as they reach into the mesquite.

Moore and Merlin locate a concentration of debris (all together, it would scarcely fill a shoebox) that marks an apparent point of impact. Moore rushes from one find to the next—an altimeter, an airspeed indicator, a fuel tank pressure gauge, and an Army-is-

sue eight-day clock. Though the time of the impact was 2:17 p.m., the clock reads 4:35. "It was probably sitting out here in the desert, still running, after they hauled away the wreckage," says Moore.

Merlin discovers tubing, battery fragments, and a piece of aluminum containing an aircraft inspection stamp from Bell—the X-1A's manufacturer. The evidence is mounting, but conclusive proof remains elusive. "I know this is it," says Moore. "But we need something positive that'll hold water."

Battery casing fragments are everywhere, and Moore finds one piece with a hand-written "1-A" on the side. Tantalizing, but not conclusive.

An hour later, he locates another piece, which fits together with the first like a jigsaw puzzle. Together, the fragments bear the inscription "X-1A." They've found the crash site.

Once they have cataloged the artifacts, recorded their discovery on a map, and photographed the crash site, the two take off for the Flight Test Museum, on the other side of the base. When they arrive a few hours later and show Doug Nelson the artifacts, the curator lights up. "Hey, you made it!" he exclaims. "That's great!"

"I knew we'd find it," Moore says, "but not that quick."

All that's left is a cold drink at Wing and a Prayer, a nearby bar and grill that caters to the aviation crowd. Proprietors Kim MacDonald and Neil Mason have filled the bar with aviation memorabilia of all types—signed photos of test pilots, instruments from B-17s, 1940s parachutes, and a two-foot piece of black nickel alloy with a plaque beneath reading "...from X-15 number 66672, recovered near Johannesburg, California, by Pete Merlin and Tony Moore, Aerospace Archeology Field Research Team." Other than the museum at Edwards, the pub is the only place where you can see artifacts recovered by Moore and Merlin. (The two aren't completely without mementos, however. On their key rings they carry a washer or fastener from each site they've located.)

What's next for the intrepid pair? "The XB-51," they answer together. "Only two were built, and both crashed," says Merlin, warming once again to the thrill of the hunt. One crash site, in Texas, has been paved over, but the other one is at Edwards.

For the moment, the pair are content to savor another discovery of relics from revolutionary aircraft—worthy additions to a collection that includes pieces of an X-2, an X-15, and the YB-49. "These planes didn't make it back to Edwards," Moore says. "We feel like we're bringing them home."

Mission to Mir

At the start of a new partnership, U.S. and Russian space travelers learn that every long journey begins with a single step.

by Tom Harpole
Photographs by Malcolm Linton/Black Star

Norm Thagard, NASA astronaut, watches intently as three men using a hand line pull fish from the lake in Star City. NASA might call this "*in situ* resource utilization." The Russians just call it dinner. In the lambent Russian twilight, Thagard approaches them, and they are instantly friendly. The Russians make a self-effacing joke as they regard their scaly little fish. Thagard alludes in halting Russian to exaggerated weights and measures and everyone laughs. To me, he adds in English, parodying his novice's accent and syntax, "You joke in foreign language, it's good." Then back in the twangless Houston accent that pervades the American space program, Thagard says, "Free food in Russia," adding a little pensively, "and they're having a good time." The latter thought seems to remind him of duty. Thagard bids the fishermen a good evening and says he must head home to review his day's notes on the Russian weightless toilet.

Thagard is part of a small NASA point team, the first Americans deployed at Star City—officially, the Gagarin Cosmonaut Training Center—to begin cooperation with the world's other space power. In March he will make history by becoming the first U.S. citizen to ride a Russian rocket and the first to work aboard the Russian space station Mir, where he will live for three months. NASA is planning to learn a lot from the Russians, who are old hands at enduring long stays in orbit. They started with a small Salyut space station in 1971 and are approaching 25 years of almost continuous presence in space. This achievement—not to mention the groping toward stable relations between Moscow and Washington—has led NASA to pursue a permanent U.S. presence in space by first pursuing a permanent U.S. presence in Star City. Thagard, Bonnie Dunbar, his mission understudy, operations director Ken

Star City residents enjoy the pastime of hooky-players everywhere, but NASA's Norm Thagard allows himself only a moment to watch.

Cameron, and Dave Ward, a physician and scientist, arrived there last February to make a foothold.

"We were going from square zero," says Cameron, a Marine colonel and astronaut. Cameron is sitting in a small two-room office—NASA's Star City headquarters, which he set up and directed until last August. It's located on the second floor of a three-story building erected in 1975 to house the U.S. side of the Apollo-Soyuz mission. The first floor serves as a pre- and post-flight quarantine to protect space crews from infection. When Cameron got there, he found two school tables, a cot, two chairs, and a rotary phone that occasionally worked. Six months and three shipments of computer and communications equipment later the place is a homely but serviceable office, where tea and coffee are served in cups with matching saucers. The dishes are washed in the bathroom sink and set to dry on a towel in a bidet that serves as a dish rack. Just outside the window a small black satellite dish that Cameron bolted to the balcony assures his connection to Houston.

Although Russian Space Agency rep-

Even their spacesuits are unfamiliar systems to which Thagard and Bonnie Dunbar must adjust.

Gennady Strekalov carries on the tradition begun by Yuri Gagarin. The mission with Thagard will be his fifth.

resentatives met the Americans at the airport and Star City director Pyotr Klimuk hosted them at a welcoming luncheon in the cosmonauts' dining hall, the NASA crew was tacitly encouraged to learn the ropes on their own. "We found out most of it just by seeing and doing," Thagard recalls. They learned how to buy necessities in the Star City shops, a challenge that forced them to practice their conversational Russian. And they encountered a few unexpected privations that compounded the stress of undertaking a new task in a foreign place with a difficult language. For instance, there were no maps of Star City to help them get their bearings in the once-secret installation. Cameron laughs now over what must have been a maddening nuisance at the time. "We had to make maps," he says. "It was a cultural difference as much as anything else. The Russians who had lived here for 10 or 20 years—there wasn't a need for a map. They knew where everything was. Typically maps from the Soviet regime were always secret."

When I ask if he could compare starting operations in Star City to a previous experience in his career, he says, "It had a feeling like a deployment. I've done some in the Marine Corps. We're such a small number and our support line—our logistics line—was so long," Cameron explains. "And the fact that it's this country in particular. We were going into what really was in a lot of ways to us just unknown. I mean it hadn't been very long [since armed revolution]. In October of the previous year, they'd been shooting downtown.

"You just couldn't even have been in here two or three years ago. It was just unheard of or impossible. And here we were. It was admittedly a very small start. We think we're making progress every day or every week."

Cameron, who managed operations for the complex Hubble Space Telescope repair mission, has a talent for seeing large, long-term projects as a series of individual tasks. "The intent is to build this international station with a lot of Russian assistance—a Russian partnership," he says. "And phase one of that is really to get started working with our partners. To learn to work together. We've got a *huge* language barrier, we've got a cultural divide, a chasm that we have to bridge, based on many many years of being on the opposite sides of a cold war. Our approaches to problems, our ways of thinking about things, our communication—there's a lot of things we have to get together on in order to make this work in space."

Cameron and his teammates are beginning to implement the agreement NASA and the Russian Space Agency forged last June. What NASA most wants from the partnership is a space station where astronauts can perform medical experiments during long-duration flights, experiments vital to future lengthy missions, like a trip to Mars. What the Americans offer is the shuttle. "That's not a small thing to offer," Thagard says. "One of the big problems they've had with their Mir station is that they don't have much ability to bring back payloads to Earth." When the shuttle that will bring Thagard back to Houston leaves Mir, it will also be carrying one of the station's gyroscopes. "There have been failures, but given the weight and size of the gyros, they haven't been able to bring one back. [This] will be the first time they've had the opportunity to determine the cause and come up with a fix for it."

The Americans also offer cash. In the first phase of a three-phase plan, NASA will pay the RSA $400 million to upgrade Mir for joint use through 1997. Phase one calls for seven shuttle-Mir dockings by December of that year. During that time five U.S. astronauts will accumulate two years of experience in the Russian station; the longest visit is planned to last five months. Phase two

Mission commander Vladimir Dezhurov (top) will leave the comforts of home on his first spaceflight. Astronauts Dunbar and Ken Cameron left a few comforts behind in the States, such as maps and clothes dryers.

As Thagard's understudy, Dunbar will probably not achieve a Gagarin-class first. But she will be on the first shuttle to dock with Mir.

(1997-1998) will see the construction of a joint American-Russian space station. During phase three, which will carry into the next century, European, Japanese, and Canadian components will be added.

Thagard's mission precedes this agreement. His tour on Mir, which will set precedents for the next four astronauts, is the reciprocal half of a quid pro quo deal that put Sergei Krikalev aboard the shuttle in February 1994 and Vladimir Titov on this February.

During the week in August I watched Thagard training, his brief dalliance at the Star City lake was the single moment I saw him spend on a matter not related to his coming mission. He was halfway through a 12-month cram course—with classes in Russian and manuals in Cyrillic—on how to operate life support, communications, power, navigation, and waste disposal systems aboard Mir and the venerable Soyuz TM rocket that will get him there. Additionally, he must learn to work with Mir's various payloads and cameras. Before launch, he will be required to take oral exams in Russian to prove his mastery of the spacecraft systems.

Thagard appears equal to the challenge. He flew F-4 Phantoms in Vietnam, is a licensed physician, and holds a master's degree in electrical engineering. He was one of 35 astronauts chosen in 1977 from over 8,000 applicants. Dan Brandenstein was running the astronaut program when Thagard was selected for the Mir-shuttle flight, and he says, "Norm was a pretty obvious choice if you read his bio. He was one of the few people in the office with a medical and engineering background."

Thagard skips breakfast and lunch. He didn't go to the U.S. Embassy Fourth of July party in Moscow because he had to stay home and study. He is training on an accelerated schedule because both sides want to take advantage of the momentum that the new partnership has provided. But he is also pushing himself hard because acing the oral exams while he's on the ground will get him more duties when he lives in Mir. He wants all the work he can get. The idea of being a symbolic passenger is anathema to him. He says: "The spirit of the quid pro quo agreement, if not the letter, was that NASA would regard cosmonauts as mission specialist astronauts—which is a NASA professional; that's what I am—and we expect them to regard us as cosmonauts and therefore considered for any normal role on the Soyuz or the Mir that a cosmonaut might fill."

When Thagard smiles his cheeks crease vertically, accentuating his athletic squareness. His thinning hair is sun-bleached. In a place where everyone seems pallid, he looks weathered, perhaps from his daily jogs around Star City. He has gone as long as five weeks without leaving the compound and admits to apprehensions that his self-imposed schedule will cause burnout before the launch.

In a classroom at the Star City training center, Thagard and his backup Bonnie Dunbar listen to Captain "Losha" (they use the affectionate appellation) Lepko explain the Russian system of life support. Lepko seems to understand how exacting the astronauts' own standards are. He teaches them Russian space jargon and gently corrects their conversational Russian.

Without Russian, one might easily believe the effusive Lepko is explaining an exotic computer game on a console with several dozen buttons and switches. Thagard works without a translator. He sometimes looks bemused, then he seems to translate the information to corresponding spacefaring data he has stored in English. He nods deeply three times, as though pumping all this together, makes a note, and refocuses on the lecture. "There's a sequential logic to learning how to operate the systems in a spacecraft that doesn't vary culturally," he says.

Immediately after being chosen to go to Star City, Thagard attended the Defense Language Institute Russian school for four and a half months. "The toughest thing is conversational Russian," he admits. "You don't have the narrow [technical] context. I understand the lectures 100 percent. But there are some Russian speakers in ordinary

Orbiting Earth since 1986, Mir has hosted 53 space travelers. The KRISTALL module, a materials processing research lab, has the only port where the shuttle can dock, but Soyuz and Progress ships can dock at other modules, which include living quarters and an astrophysics observatory. An Earth sciences lab, SPEKTR, will be added to Mir in June.

COMPUTER GRAPHIC CREATED BY JOHN FRASSANITO AND ASSOCIATES

conversation that I understand virtually nothing of what they say."

Thagard and Dunbar work in both the Mir and the Soyuz mockups. Dunbar recalls the first time she nestled in her gray canvas sling seat inside the Soyuz command module, where the controls curve from the floor to overhead. There are hundreds of push buttons, toggle switches, thumb wheels, and what look like Bakelite circuit breakers. All, of course, are labeled in Cyrillic characters. "The only familiar thing in there were the numbers," she says.

Star City's Mir mockup has outgrown a building that could handle two basketball courts. Its newer modules, KVANT and KRISTALL, are nearby but unattached. In space, the five-module Mir appears as an enormous tubular

cross. Its wing-like photovoltaic panels look frail as ribbons. Latticework masts poke up five stories tall. The shuttle, with its cargo doors open, will dock with the Mir like a bird attached by its cervical spine to one end of a cosmic crucifix. "It's thrilling to approach the little satellites we bring home," shuttle veteran Ken Cameron says. "It will be overwhelming to see the size of Mir in space and to fly up to it knowing the people in it." A shuttle crew will get their first look this February, on Discovery's mission to rendezvous but not dock with the station.

The Mir interior reflects Russian studies in spacefaring psychology that Thagard would like to see adapted in all spacecraft. The color scheme, he notes, is consistent throughout the five modules. To negate the disorientation of weightlessness, where there is no up or down, the floors are all rose-colored, the walls a baby blue, and the ceiling the diffuse gray of an overcast sky. Additionally, every equipment cover, locker, and access panel is numbered, denoting how far forward or aft the item is located.

Perhaps the most unpleasant aspect of life aboard Mir is the noise. With all the life support systems, pumps, motors, and fans, Mir's audio ambiance is "somewhat like the inside of a vacuum cleaner," according to Gennady Strekalov, a veteran cosmonaut whose mission with Thagard will be his fifth spaceflight and his second stay on Mir. "But it doesn't preclude normal conversational tones." The sudden absence of a part of the background noise can be far more disconcerting. "Any little change in the sounds inside the space station is very troubling. It will wake you up," says Strekalov. "But I've spent so much time in the space station that with help from ground control, I can handle any problems." Strekalov lived on Mir for 132 days in 1990.

Thagard says he takes comfort from the fact that Strekalov is so knowledgeable about the Soyuz and Mir. He also finds his 54-year-old colleague among the most amiable and professional people in the Russian space program. "We haven't spent much time together, but when we do there's a good feeling there," he says.

Strekalov, who may have been softened by a desk job as a civilian engineer for the Russian design institute NPO Energia, marvels at Thagard's voluntary physical regimen. The cosmonaut's canny, perpetually content face retains the slight puffiness of his many months of weightlessness the way Thagard's holds a residual Houston tan. He describes Thagard's training as one would brag about the achievements of a prodigious friend. "We would spend two years or longer to learn what Norm is doing in one year, and he's doing it in a foreign language," Strekalov says.

Vladimir Dezhurov, the 33-year-old mission commander, is a muscular former fighter pilot who radiates willingness. He has trained since 1986 for this, his first spaceflight, and approaches his mission with a characteristic Russian romanticism. "It would be unnatural for only one culture to explore space," he says. Thagard appreciates Dezhurov in his thoughtful, trenchant way. "Volodya," he says, using the affectionate form of Vladimir, "is so confident as mission commander that he doesn't ride herd on anyone."

Because of the accelerated schedule, Strekalov, Dezhurov, and Thagard will train together as a crew only for the last few months before the flight, and Russian trainers are watching closely for

Immersed in preparation for his mission, Thagard readies his body and mind. He swims daily (opposite) and spends hours practicing in the Soyuz simulator. When he's not exercising or in a simulation, he's in the classroom.

any signs of incompatibility. Dunbar and Thagard spent two days of winter survival training under Dezhurov's command in March, and when they got back to Star City, the first question their trainers asked them was "What did you think of Vladimir?" Thagard called him "good company" and added, "We all were. Explorers, by nature, are tolerant."

Both sides will undoubtedly make accommodations. Thagard is accus-

tomed to working, unofficially, 20-hour days for a week or more in the shuttle. He has lost 23 pounds in his four shuttle flights, a fact he mentions with a hint of pride in having worked long and hard every time he has orbited. Sustaining that pace for three months in Mir, he realizes, would be impossible, although he has no plans for leisure time other than playing a couple of computer games he might take along. He shrugs and allows that he "really enjoys a little window time in orbit."

During his 90 days aboard Mir, Thagard will manage a suite of 20 experiments to assess the human reaction to microgravity, a medical agenda that a team of U.S. and Russian life scientists hammered out last summer at the Institute of Biomedical Problems in Moscow. Using technologies like a cardiac echo Doppler device to measure the size and shape of the heart and the rate of flow through blood vessels, Thagard will be studying his own and his crewmates' bodies for reports to both Russian and U.S. investigators. His work will be complicated by a delay in the launch of the SPEKTR module, a Russian-built annex to Mir carrying Russian remote-sensing cameras and stuffed with 1,600 pounds of U.S. electronics and life sciences instruments. There were two equally thorny problems with the module: integrating U.S. equipment with Russian hardware and getting U.S. products through Russian customs. Both have apparently been overcome and the SPEKTR will be launched in June. In the meantime, the Russians are shipping 251 pounds of U.S. research hardware, including a blood collection kit, frozen urine and frozen saliva kits, and a thermal electric freezer, on a Progress vehicle in February. "Norman's still going to have plenty of work to do," says Ken Cameron. "We're going to get a lot out of this joint mission even if all our equipment doesn't make it up there the first time."

Merging the two countries' life sciences research entailed other cultural complications that, six months before the flight, remained to be resolved. Although the Russians have shared the results of their decades of experimentation and observation on the effects of long-duration weightlessness, U.S. researchers have had difficulty interpreting the results. Victor Schneider of NASA's Division of Life and Biomedical Science Applications explains that in the past, the two sides used incompatible measuring tools and standards. "If you are trying to get a basic reading on, for example, a blood sugar level, even in different laboratories within the United States, you'll find inconsistencies," he says. "What one lab would say is a low value could be called normal or high in another lab. There are differences in the definitions of normal. There are also differences in readings based on the use of different equipment or techniques."

The fact that Thagard and his crewmates will be the 54th, 55th, and 56th people on Mir represents a further difficulty in drawing conclusions from the Russian studies of the effects of microgravity. Medical studies on Earth routinely use more than 100 subjects and have a large group of control subjects as well. The number of experimental subjects that have been on Mir is still too small to enable scientists to conclude which countermeasures can be used to control which effects.

"It hasn't been easy settling on the medical agenda," says Dave Ward, the

Thagard's self-imposed physical regimen includes a daily jog, usually past a statue of Russia's first cosmonaut (opposite). His reward: a few minutes in one place in Star City with no likeness of Gagarin.

soft-spoken NASA flight surgeon in residence at Star City. "There's been much discussion, misunderstanding, disagreements, and many cultural accommodations on both sides. Russians do science a little bit differently than we do. From the perspective of medicine, they use an Eastern-type approach, which is problem-oriented. They see a problem, they try several things at one time to fix it and they don't know exactly which one worked. Russians, I think, by nature are very creative and innovative. If you look at the West, we've evolved a type of science that's very specific and methodical. Our kind of science takes a lot of time and energy and a lot of people in your study."

One of the Russian habits Ward admires and would like to see Americans imitate is swift decision-making. "If someone here proposes a change in a program and it makes sense, a couple days later you see it in the conspects [the booklets that delineate every procedure]," he says. "In NASA too many people have a voice in change. The same proposal can take months and often gets so bogged down in review process that even the simplest changes never make it."

Regardless of the differences between the Russian and U.S. space programs,

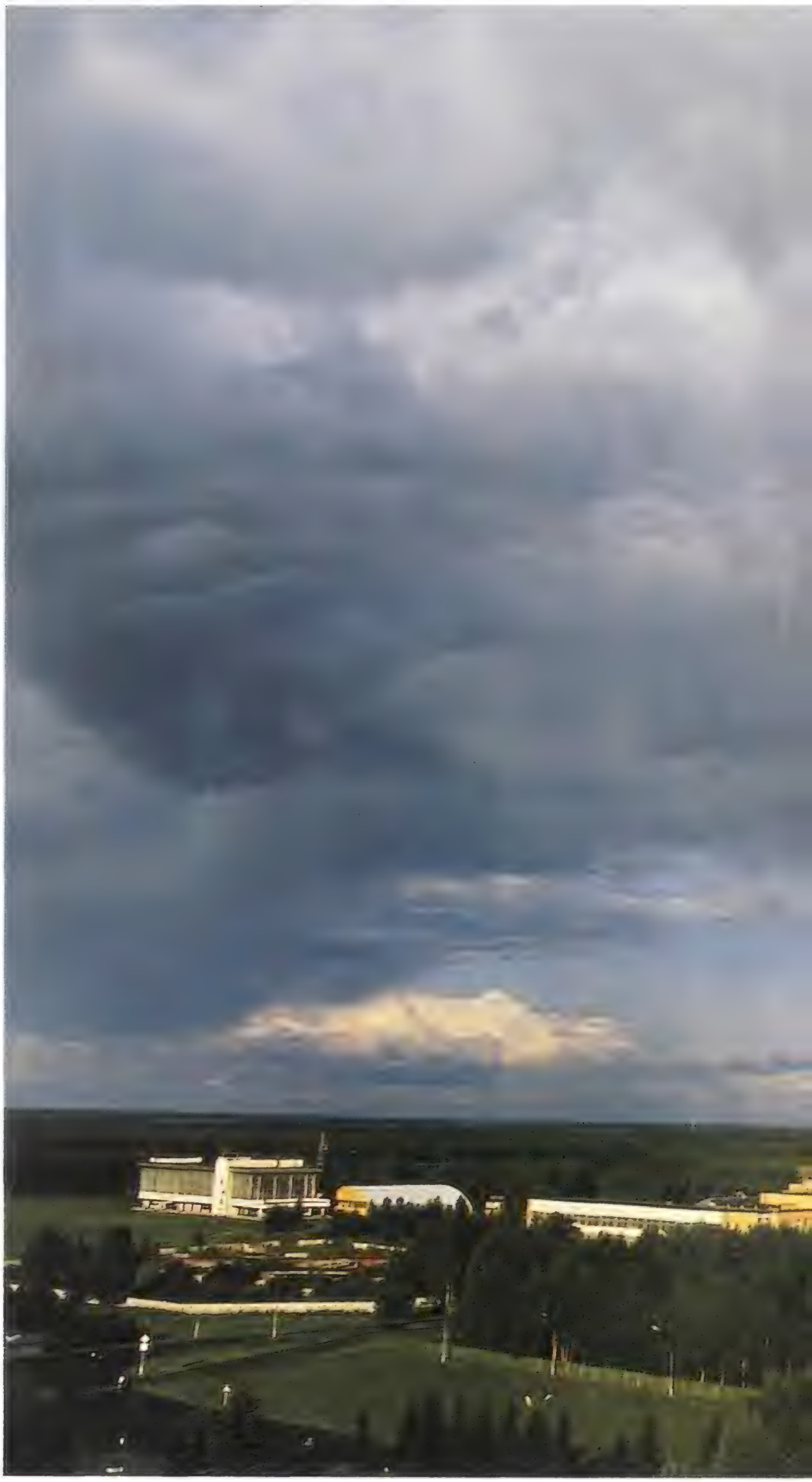
there is at least one overriding similarity of purpose. All of the long-duration studies, the plans for construction of an international space station, the biomedical experimentation, and the new attempt at partnership are aimed at getting to Mars. In an odd twist for a country that at one time had so many secrets, the Russians have been more explicit about this goal than the Americans. For decades the slogan of the Soviet space program has been "On to Mars." "Russian people and a lot of the Americans really feel that our best business is to get off the Earth, get to the moon, and go on to Mars," says Ken Cameron.

Hurrying after Thagard one day as he hustled from one class to the next, I asked about his philosophical projections—what he thinks his mission means in a larger context. Will it lead to an expansion of the human habitat? Will we one day go to Mars and beyond?

"I can't think that far ahead," he answered, his unfaltering footsteps echoing in the long hallway. "I can only think about this mission. We're studying life science, learning more about the human organism in microgravity. The engineering and navigation to get to Mars we can do." Thagard slowed his pace, nodded his head deeply three times, and said, "Incrementally, inevitably, we'll keep going out there."

Inspired by Star City sculpture, these children conduct their own experiments with gravity. If they are to have a future in space, the Russians will have to keep the once-secret cosmonaut training center (left) open to international partners.

IRINA KUZNETSOVA (2)



The Awe-Ja-Magic Fly-In Pancake Breakfast

All it's missing is a fly-through window.

by Stephan Wilkinson

Illustrations by Richard Thompson

In the valley below, fog rose from Lake Seneca while the sun climbed quickly into the chilly September sky. I was shivering on my folding bicycle, pedaling from a Dundee, New York bed-and-breakfast to a tiny Finger Lakes grass strip nearby, where my little Falco—the airplane I had built in my barn and was finally putting to good use—had slept overnight. At 6:30 on a Labor Day morning, nobody was on the road, save one teenager who wailed past in a ratty black Camaro, foot to the floormat, the engine sucking air like a wild thing. The driver knew he had nothing to fear: there wasn't a state trooper between Rochester and Ithaca who'd had his first glazed doughnut yet.

At the airstrip, however, things were a-bustle, for this was the morning of the annual Dundee Flying Club Labor Day Fly-In Breakfast, an event as monumental to this town of 1,500 as the Rose Bowl parade is to Pasadena. On the dew-soaked runway stood several men in orange vests, signal paddles in hand, ears cocked for the lazy hum of a distant airplane. "Here comes a customer," said one as a bright yellow Piper Pacer muttered into the pattern. By 7:30 the flow had begun—a steady stream of pilots who, for lack of anything better to do, had flown dozens and even hundreds of miles to eat pancakes with their cohorts. Not having

the stamina to roust myself at 4:30 to arrive by air at 7:00, I'd flown in the afternoon before, transferring from Falco to baggage compartment two-wheeler.

The Experimental Aircraft Association, by far the world's largest organization of sport pilots, estimates that 10 to 20 major EAA-sanctioned fly-in breakfasts are held in the country every weekend between early April and the end of October, with countless more held by unaffiliated local groups such as the Dundee Flying Club. Fly-in breakfasts are just one manifestation of the American lightplane pilot's seemingly constant quest for food—a quest so unremitting, in fact, that it is an effective inflation index: what in the 1930s was called "the 50-cent hamburger" had by the 1960s become the $20 burger and is today $100 on a bun. It is the greasy patty served at any airport cafe somewhere over the horizon, half an hour's flight—and the expense it entails—away. And this despite the fact that some of the vilest, plainest, unrepentantly unhealthiest food in the United States is served at small-airport cafes. They are the last bastion of Route 66 home cooking. In fact, one explanation for the popularity of fly-in breakfasts may well be that the lunches at airport restaurants in the early days of general aviation were so bad that pilots generally made their cafe jaunts in search of breakfasts, which were harder to ruin.

Al Stivers, one of the organizers of the Dundee affair, thinks that fly-in breakfasts grew in popularity "because there were way too many church dinners already, and pilots were looking for something else to do." Stivers ought to know, since he's an Episcopal priest.

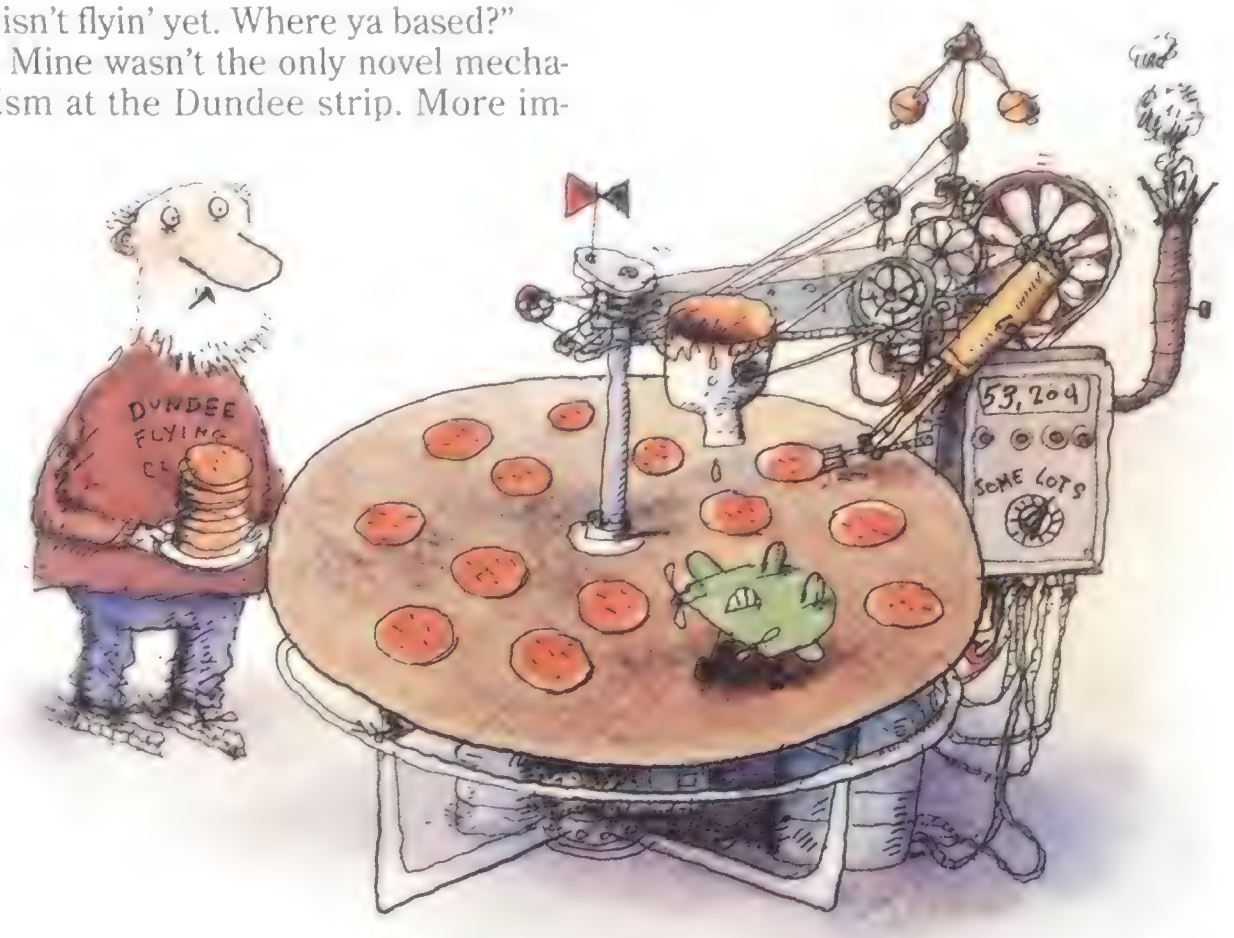
Of course, there are other reasons for the popularity of fly-in breakfasts. Many pilots were—and still are—farmers, accustomed to getting their days under way early. If they wanted a little weekend time to play with their airplanes, it would have to be first thing in the morning. Indeed, outposts of the Flying Farmers, a national club of aviating agrarians, have been hosting fly-in breakfasts since the 1940s. "I went to my first one in 1952, in Fairview, Oklahoma," says longtime Flying Farmer member Arlene Babb. "Why breakfasts? Well, breakfast is a cheaper meal to prepare, and if pilots have to come a long way to the breakfast, that gives them the rest of the day to get back home again," she says.

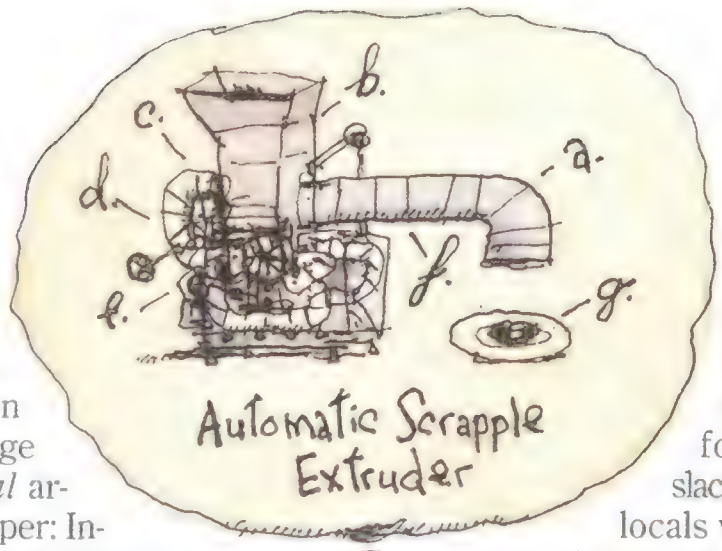
Mornings are the most delightful time to fly, free of the heat of the day, the air smooth and the crosswinds still, afternoon thunderstorms still half a day away. And though some of the breakfasters at Dundee flew Boeing 767s and worked as air traffic controllers in the real world, others were bound by tighter aerial leashes that made a simple dawn patrol an adventure. "Yeah, I remember a while ago making a cross-country in a Cherokee down to Westchester County Airport, near White Plains," one of them recalled. "Two and a half hours down, two and a half days back. Weather moved in."

Yesterday afternoon, when I'd fluttered out of a hot September sky and bounced onto the grass, four local pilots gathered to assess my arrival. They strolled over and politely inspected the garish little Falco while I tied it down. Painted like an Italian military trainer, it turns heads even among old-timer aviators, who invariably maintain a "seen 'em all, flown the crates they came in" demeanor.

"What's she made of, fiberglass? *Wood?* You don't say! That's a 160 Lycoming? One-*eighty*? Yuh, she must move right along. Fella up to Penn Yan's been buildin' one of them Glasairs, but it isn't flyin' yet. Where ya based?"

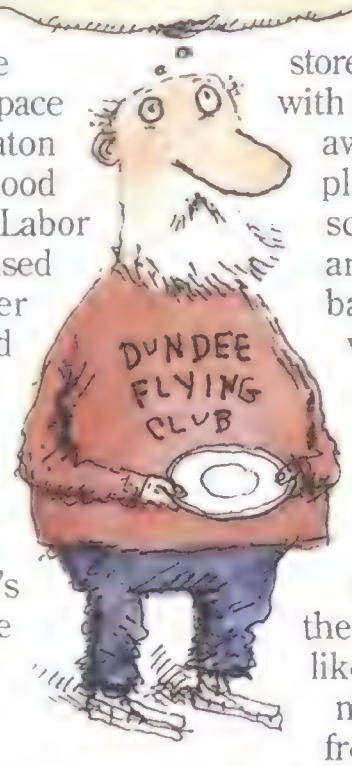
Mine wasn't the only novel mechanism at the Dundee strip. More impressive by far was local craftsman-tinkerer-inventor Clarence Sebring's automatic pancake-making device—officially the Awe-Ja-Magic Machine, so named for his grandson's mispronunciation of its prime attribute. And automatic it by-God is. A large doughnut-shaped steel millstone revolves with stately precision beneath a funnel-like batter dispenser. The dispenser plops forth a dollop of batter every few seconds, and as gears and levers, cranks and cams obediently cycle, each of 15 pancakes makes a lap of the cooker before being flipped by a disembodied spatula onto a new track on the periphery of the hot wheel. Amid the *psssssss* of compressed air and the hum of an electric motor, another revolution later a scoop briskly slides under the perfectly cooked pancake and tips it onto a paper plate. Complete with a digital counter that tracks the morning's production, plus a "Sebring" logo in chrome script from a 1971 Plymouth coupe—"I go to junkyards and pick them up, put 'em on my various projects," Clarence confided—the Awe-Ja-Magic is a combination of Rube Goldberg monkey-motion and Jean Tinguely artistry, a larger-than-life version of the rolling-balls, tilting-seesaws, racheting-racks machines that the Swiss consider a major artform.





Dundee looked as sleepy as a mutt in the sun, but the first assault on the little farming town's anonymity had been a June 1993 front page *Wall Street Journal* article, "Flapjack Flipper: Inventor Sebring Has a Machine To Do It." The fly-in has grown apace since news of Sebring's automaton spread. "Oh yeah, and we had 'Good Morning America' up here last Labor Day—they broadcast live," enthused Dundee Christmas-tree farmer Joe Sullivan. "And then 'Beyond 2000' came in October to shoot Clarence's machine." Even as we spoke, a TV documentary crew was clamping lights and diffusers onto the weathered joists of the Dundee Flying Club's ramshackle row of shed-like hangars, setting up to tape Sebring and his Awe-Ja-Magic Machine.

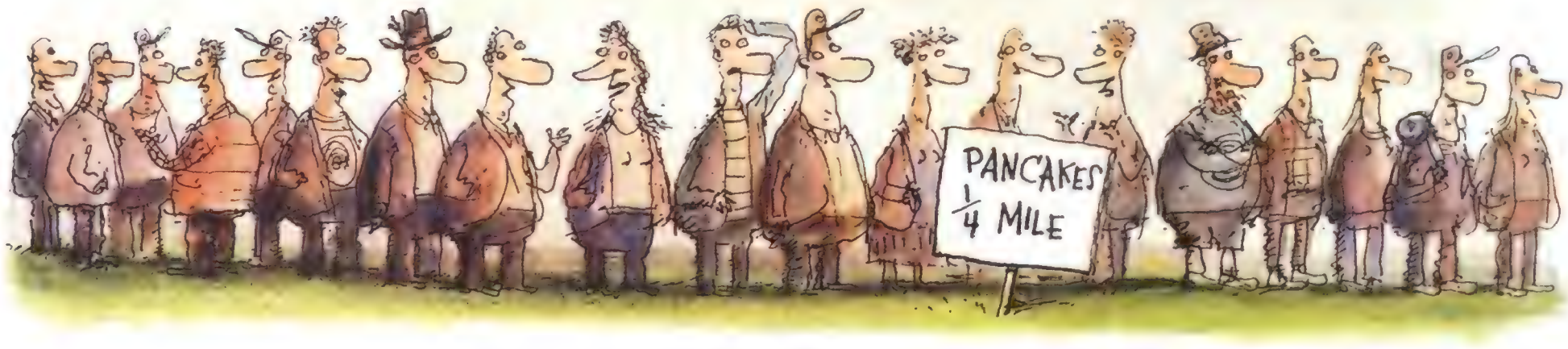
Meanwhile, the line for breakfast grew faster than the Awe-Ja-Magic's immutable spew, though a backup gang of old-fashioned human pancake-flippers and egg-fryers did a good imitation of automata. "This is the longest line I've ever been in," groaned Jonas Dovydenas, a pilot who'd arrived late from Pittsfield, Massachusetts, with his wife Betsy. "There are visa lines in Cuba shorter than this. I figure we're in the fly-in lunch section, and everybody behind us is here for dinner."



Conversations sprang up, war stories got told, Finger Lakes summer yachts-folk in gaudy slacks chatted with locals wearing feed-store gimme caps, pilots yarned with Harley riders. And yards away, a flurry of small airplanes taxied and blatted, scurried about and parked, and impatiently bounded back into the air. The strip was short and rolling—really just a well-mowed pasture—and the approach from the north over a grove of tall trees was a bit tricky, making perhaps the first 300 feet of the runway unusable. Yet unlike the weekend scenes at mainstream airports, where frenzied inepts bounce and wheelbarrow along with tires screeching, every pilot finessed his or her approach and landing. Hardly a one failed to turn off at the middle of what was essentially a 2,400-foot strip. These weren't weekend Spam-can drivers but flying farmers, experimental-airplane builders, vintage-aircraft restorers, and airline pilots on their day off.

The Cessnas, Pipers, and Bonanzas turned right to park among the corn and alfalfa. The less tractable and more interesting biplanes and taildraggers were signalled left, to primp and pirouette alongside the breakfast line: a Bücker Jungmann in the colors of a German "civilian" pre-war training unit, spindly landing gear as firmly outthrust as the forelegs of a puppy at the end of a leash; a superbly restored Stearman, its 220-horsepower Continental radial chuffing like a steam engine; a silver Stinson 108 wearing the yellow and red roundel of a Spanish Air Force liaison plane, even more unlikely than my Falco's phony Italian "Aeronautica Militare" costume; and most unlikely of all, a miniature Junkers Ju 87 Stuka, bigger than a large lightplane but little more than half the size of the German dive bomber it aped. Whoever built it had gone to enormous effort to create an exact replica of one of the ugliest, most malevolent airplanes ever produced—a dump truck for bombs.

There aren't many fly-in breakfasts with as long and splendid a history as Dundee's, which has been held twice every year since 1965, on Memorial Day and Labor Day. The Flying Club kitchen cycled through some 1,600 fly-in and drive-in breakfasters last September, and the men in yellow vests parked over 100 airplanes. But if you're planning to attend next Memorial Day, you'd better arrive early: Clarence Sebring hopes to introduce a second Awe-Ja-Magic device that he's been perfecting for over a year now. While his flapjack carousel continues its stately dance, his new egg-frying machine will be over-easying a steady parade of eggs, one every seven seconds, the white of each exactly four inches in diameter. Be there.



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COMMENTARY:

Six Ways Back to NASA Greatness

In the months leading up to the launch of the Hubble Space Telescope in the spring of 1990, I had occasion to be at the Kennedy Space Center in Florida several times while the bird was being prepped for flight. In my free time, I would walk around the facility, imagining what it must have been like in days gone by. On one particularly sunny winter day, I was admiring a huge Saturn V rocket, now lying on its side, when it dawned on me. They had done it—not just once, but six times; they had transported men and machines to the moon's surface and brought them back safely six times. What a class act! "They," of course, were the men and women of the "old" NASA.

By contrast, the "new" NASA—today's U.S. space agency—seems to have become just another government organization. Its agenda is politicized, its credibility shot, its leadership lacking, its management bureaucratized, its rank-and-file demoralized, its vision cloudy at best.

Since the glory days of Apollo, NASA has increasingly gotten itself trapped in a regular, almost traditional cycle of lowballing the costs of its space missions to get them approved, overselling those missions to keep them funded (often despite large cost overruns), and, with few exceptions, failing to deliver on its promises.

I joined the Hubble project in the mid-1980s as a senior scientist at the Space Telescope Science Institute in Baltimore, the scientific nerve center of the mission. More importantly, I joined as an unabashed space enthusiast: not a space cadet with NASA mission patches sewn all over an imitation flight jacket, but rather an astronomer eager to explore space with a whole new array of spacecraft dedicated to unlocking secrets of the universe. By the time I left in the early 1990s, however, I had evolved into a harsh critic of the way NASA does business.

Yet NASA-bashing is not my aim here. Having lived the Hubble project morning, noon, and night for several years, I can offer a personal perspective of what NASA needs to do to identify a path for reform and a way back to true greatness as a classy organization embodying the best in our technological society. Six categories of reform, not meant to be definitive, come to mind immediately.

Technical truth NASA exaggerates virtually everything these days. For example, soon after deployment, when the Hubble telescope ran into one problem after another, NASA regularly issued all-is-well bulletins until it could no longer hold back the truth. Then its leaders took a 180-degree turn when Hubble's chief scientist announced on live television that "no real science can be done with its cameras"—another distortion that led almost everyone to believe that Hubble was broken, a useless piece of junk. Now, in the after-

Eric J. Chaisson offers a formula for building a better space agency.

math of its dramatic repair mission last year, NASA again exaggerates Hubble's status—its administrator himself claiming at a press conference that "Hubble now exceeds its original specifications," a wishful statement known to be false. Other exaggerations abound, and not just about the Hubble mission.

If NASA management were to explain effectively, based on technical truth and an absence of hype, what it had done, what it is now doing, and what it would like to do next, it might avoid annual budget crises, Congressional micromanagement, an ongoing lack of public confidence, and deep and bitter frustrations within the agency itself. Only with a reform-minded leadership that values honesty can NASA break out of a bureaucratic morass that rewards mediocrity and self-preservation while damping innovation and creativity.

Scientific integrity Even science findings from NASA's successful missions are often exaggerated, thus corrupting the science and misinforming the public. Because seemingly everything the space agency announces has to be the biggest or the brightest or the best or the first, it has become difficult to believe NASA at all.

As only one case in point, take Hubble's much heralded announcement of a "major discovery" of a black hole in one of the Virgo galaxies some 50 million light-years away. That Hubble's instruments were able to provide significant evidence of a black hole's existence is a good, solid piece of science—one that I quickly incorporated into my introductory college textbook. But then NASA spoiled it when one of its lead scientists argued before the world's television cameras that the result is a "totally unexpected finding," an exaggeration that the media soaked up like a sponge. Actually, virtually every professional astronomer expected Hubble to find essentially what it did. In fact, during the press conference in Washington announcing the "discovery," NASA officials showed an accurate video animation of the Virgo galaxy's heart that a computer artist and I had made four years earlier—before Hubble was even launched.

Because seemingly everything the space agency announces has to be the biggest or the brightest or the best or the first, it has become difficult to believe NASA at all.

NASA's public relations machine must not tamper with the cherished concept of scientific integrity. To hype a space mission before Congress to get it funded may be tolerable to some, but to continue that hype right on through the release of the scientific results is plainly unacceptable.

Systems thinking If there is a prime lesson to be learned from the Hubble mission, it is the need for better *systems* management, *systems* engineering, *systems* analysis and design. Few in the Hubble project appeared to have recognized the importance of building, testing, and operating the space vehicle as a whole, rather than in pieces. Much as occurs in the highly specialized university departments where scientists and engineers are trained, hardly anyone saw the bigger picture.

It is imperative for complex space vehicles—as well as for many of the increasingly complex gadgets of our everyday world on Earth—that we embrace the concept of systems thinking, of holistic design, construction, and application. Otherwise, the idea of "the whole being greater than the sum of the parts" can be turned on its head and a collection of well-made parts that function in isolation can, as a system, not function well at all.

Project accountability The Hubble project was hobbled from the start, owing chiefly to the fact that three competing NASA centers were interfacing with multiple major contractors and literally hundreds of subcontractors—in all, a cast of some 10,000 individuals toiling for more than a decade largely independently of one another. Hubble's

The author directs the Wright Center for Innovative Science Education at Tufts University, and recently wrote *The Hubble Wars: Astrophysics Meets Astropolitics in the Two-Billion-Dollar Struggle over the Hubble Space Telescope.*

end-users—the astronomers of the world—were only minimally consulted in its R&D. (By contrast, the repair of the telescope's vision is testimony to the intimate involvement of the scientists of the Space Telescope Science Institute.) In short, when it all hit the fan soon after Hubble's launch, no one group or person was accountable for the fiasco.

That there ought to be a single entity responsible for each NASA mission, from birth to death, seems like common sense. But in the real world, big science is politicized—designed to spread around the money and the obligations as thinly as possible to gain widespread support. This is what happened to Hubble years ago, and this is clearly what is happening to the space station project now.

Educational programming Despite all its rhetoric about education, NASA built history's most expensive and visible scientific instrument without having any associated educational program. No part of the space agency had any plans to share the fruits of Hubble's discoveries with the nation's youngsters. What's more, virtually every pre-college educational initiative that I mounted at the Space Telescope Science Institute was accomplished *despite* NASA. Citing the need for editorial control, the space agency regularly and consistently objected to the institute's teacher workshops, media briefings, teacher kits, classroom posters, and educational telecasts, and a host of other activities and products designed to help teachers, students, and the general public understand the subject of space science in general and the Hubble mission in particular.

Each NASA mission should have a small educational program meant to disseminate new findings in a manner understandable to the average citizen. To the question that Senate staffers used to ask me—"How much education is needed?"—I would reply, "One percent." If only one percent of each mission's funding were dedicated to informing the educational and lay communities in a responsible way, namely without hype, then NASA would be well served, and so would the public that underwrites NASA.

NASA's public relations machine must not tamper with the cherished concept of scientific integrity.

There is one critical caveat here, however. Those NASA missions that do have educational programs intended to propagate fact must be divorced from public affairs activities that tend toward cheerleading. The former are clearly tainted by the latter, which often border on disinformation. From what I have seen on the inside, NASA's public relations machine—technically inept, yet obsessed with winning credit for NASA—should be nearly gutted, for it actually does a great disservice to the agency.

NASA's vision American taxpayers generally do not know what NASA is doing these days; they have less understanding of what NASA would like to do in the future. Nor do they seem to care anymore. Survey after survey in recent years has made clear that the majority of people no longer get excited about what NASA does in space.

This apathy is NASA's own doing. First, because it seeks to generate the perception that spaceflight is routine, spaceflight seems boring. And second, because the space agency has no vision, there exists no grand goal or understandable plan around which our citizens can rally.

Make no mistake that that vision can simply be an apparent change in attitude, such as the currently fashionable "faster, better, cheaper" slogan heard inside the Beltway. For even here there is open hypocrisy on NASA's part: the agency still spends most of its time trying to salvage the multibillion-dollar projects, such as the space station, the Cassini mission to Saturn, and remnants of the Great Observatories. And just as space shuttle development and operations in the post-Apollo years brought the golden age of robotic planetary exploration to a virtual end, the space extravaganzas—especially the space station—will irreversibly harm smaller missions for the rest of our lives.

The "new" NASA desperately needs to develop a *raison d'être*—not a vague strategic plan or cryptic technical blueprint, but a warm and engaging vision for its future that the typical non-scientist can appreciate, from Congressman to third-grader alike. NASA needs to decide what it wants to do, to step up to the plate and articulate its rationale, and most of all to make clear to the tax-paying public why we have a space program at all.

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THE LATEST WORD ON TOURS, EXPEDITIONS AND LEARNING ADVENTURES

THE SECRET WEAPON

by Don Sherman

Frau Lang never heard the drafting pen skimming across tracing paper. While she slumbered in her Queens, New York apartment in the fall of 1937, her husband Hermann toiled like a monk at the kitchen table, copying complex blueprints. By day the 35-year-old naturalized German immigrant and loving father worked as a machinist, draftsman, and assembly inspector at Carl L. Norden, Incorporated, in Manhattan. By night Lang was a traitor and spy, code-named "Paul," who was bent on compromising what would be America's second most important World War II asset—the Norden bombsight.

Lang helped smuggle his copies of the bombsight blueprints aboard German cruise ships and traveled to the fatherland to assist in the assembly of a copy. There he was toasted by Luftwaffe chief Hermann Goering and received a payment of $3,000 from the Third Reich. Eventually betrayed by a double agent, Lang was arrested by the FBI and tried in the grandest espionage case in U.S. history as one of the "Nazi Nineteen." He was convicted in federal court and sentenced to 18 years in prison.

Ironically, when war broke out the Luftwaffe had little use for the Norden, because instead of high-altitude level bombing, for which the sight was applicable, it chose to emphasize dive bombing. Yet Lang's betrayal added to the mystique that shrouded the Norden sight like a phantom's cloak. Much of the lore about the device that survives even today—that human hair donated by Mary Babnick Brown of Pueblo, Colorado, was used for the instrument's crosshairs; that when Patton's Third Army swept through Austria, a secret German factory was found producing Norden bombsights; and that American bombardiers could readily drop a bomb into a pickle barrel from 20,000 feet—is false.

This is not to suggest that the Norden bombsight was a hoax. To the contrary, Major General Benjamin Foulois, Army Air Corps chief in the early 1930s, proclaimed it "the most important military secret project under development by the Air Corps." Auburn University historian Stephen McFarland, who has written a book about U.S. bombing techniques, ranks the Norden bombsight as "the most sophisticated and most secret military weapon in America" prior to the Manhattan Project.

Essentially, the Norden bombsight was a mechanical analog computer, designed to determine the exact moment bombs needed to be released in order to hit their target. The bombardier's job was to "program" the computer with the information it needed. On the bombing run, the sight would fly the aircraft and determine the proper point at which to drop the bombs (see "The Bombardier's Computer," p. 85).

On a broader scale, the Norden instrument provided a technical foundation for America's precision strategic bombing doctrine—the hope of destroying an enemy's industrial base, and thus its means to fight, from high in the heavens, beyond the reach of defensive artillery. By the time the U.S. entered the war in 1941, its air war plan was based on the assumption that the most efficient way to defeat an enemy is to destroy its capacity to wage war. By flying in daylight at high altitudes, strategic thinkers believed, bomber formations could defend themselves on the way to their targets and, once there, destroy the enemy's industrial infrastructure with precision. The doctrine was boldly innovative, but like any battle plan conceived during peacetime, it proved severely flawed when tested under the harsh realities of war.

The Norden bombsight was touted as a war-winning piece of equipment, so valuable that bombardiers were asked to guard it with their lives. That reputation may have been somewhat exaggerated.

DAN PATTERSON

Boeing B-17s carry out their part of the U.S. bombing offensive (above and opposite). For their strategic bombing to work, the bombardiers needed a bombsight that could attack targets with precision. From his position in a bomber's nose (opposite, below) a bombardier would program the Norden sight in preparation for the run. The sight would take over from there, even releasing the bombs (left).

As secret weapons go, the Norden bombsight and the atomic bomb were a study in contrasts. The Norden device initiated the U.S. battle against the Axis powers; the A-bomb ended it. While Norden was practically a household word by the end of the war, only a handful of people knew of the atomic bomb before it exploded into headlines. The Norden sight supposedly allowed airmen to pick off strategic targets as frontier marksmen would, while the atom bomb waged war by annihilating entire cities in one flash. The two secret weapons first intersected on August 6, 1945, when Major Thomas Ferebee, a 24-year-old bombardier with 63 combat missions under his belt, used a Norden sight to drop an atomic bomb from the *Enola Gay*, a B-29 flying 31,000 feet above Hiroshima.

Bombardiers liked to boast that with the Norden bombsight they could drop a bomb into a pickle barrel from 20,000 feet. When asked if that was true, inventor Carl Norden often responded, "Which pickle would you like to hit?"

Norden, born in 1880 in Semarang, Java, to Dutch parents, was far too shrewd to give a straight answer to that question. Although he had an artist's temperament, Norden studied mechanical engineering at the Federal Polytechnic Institute in Zurich. In 1904 a wealthy uncle helped Norden immigrate to America. There, seven years later, the brilliant inventor Elmer Sperry hired him to work on ship gyro-stabilizers. Their relationship soon soured—Sperry despised Norden's appetite for "vile, black cigars," while Norden resented his former employer's suggestion that any of his future patents related to gyro-stabilizers be assigned to the Sperry Gyroscope Company. It was the beginning of a bitter rivalry lasting decades. In 1913 Norden struck out on his own, though the two mechanical geniuses collaborated on various military projects through World War I.

McFarland paints a particularly vivid picture of the Dutch master. "Norden was a man of immense nervous energy, excitable, and volatile, with an unholy temper," he writes. "The

Navy referred to him as 'Old Man Dynamite.' He had a pronounced disdain for lesser minds to the extent that he was generally unsociable and reclusive. One major reason for Norden's penchant for privacy was his exacting standards that few could meet. He liked always to start with a blank sheet of paper rather than first ascertaining what others had done. He had no extensive library, relying on his slide rule, a book of engineering tables, and a few basic manuals."

Norden, who made three attempts to become a U.S. citizen before he finally gave up, began his bombsight work in 1920 for the Navy's Bureau of Ordnance. In its search for an effective means of sinking enemy ships, the Navy had studied level bombing, dive bombing, glide bombing, and aerial torpedo attack. Norden's initial assignment was to improve on the state of the art, a World War I bombsight designed by Harry Wimperis of the British Royal Navy. It was a crude device—little more than a board fitted with a bubble level and two adjustable rifle sights—and the bombs it aimed seldom struck within hundreds

NASM

DAN PATTERSON

of feet of their targets. A primary reason for the inaccuracy was the random pitch and roll of the aircraft during the bomb run.

Norden added gyro-stabilization, a telescope for better sighting of the target, and a means of signalling flight directions to the pilot. When results were unsatisfactory, he retreated to his drafting board to design an all-new sight at his own expense. In support, the Navy sent him a collaborator with a reputation for getting the job done: Theodore Barth, an engineer and ex-Army colonel who had been in charge of gas mask production during World War I.

Their meeting in 1923 was the serendipitous fusing of mind and spirit. Barth soon became the catalyst for Norden's genius. He also supplied critical qualities his partner lacked: charm, diplomacy, and a head for business. The two men became close friends.

Progress in bombsight development was still painfully slow. Tests in 1925 of the new Norden sight at the Navy's Dahlgren, Virginia proving ground were disappointing, and bombardiers complained that operating the device demanded both hands, both feet, and their teeth. Norden made improvements but problems persisted. Irrationally, the Navy pushed for a production contract for this Mark XI device. Norden and Barth resisted, but in 1928 they agreed to establish Carl L. Norden, Incorporated, to fulfill Navy orders.

Through verbal agreements and written contracts, which weren't strictly legal because they sidestepped the procurement process, particularly competitive bidding, the Norden firm became the Navy's designated bombsight development laboratory and production facility. Machiavellian measures were used to hold at bay the two entities most likely to challenge the scheme—Norden's archrival, the Sperry Gyroscope Company, and the Army Air Corps: all forthcoming patents were assigned to the Navy, and the illicit Navy-Norden liaison was wrapped beneath a secret security blanket.

During the 1920s the Army had been searching for a satisfactory bombsight. Though no successful model was developed, Elmer Sperry Jr. had made significant progress in stabilizing the bombing platform with an autopilot he had designed. That resulted in a cozy relationship between Sperry and the Army Air Corps similar to the Norden-Navy deal, with the Army using a Sperry bombsight that was inferior to the Norden. In 1932 the Army and Navy finally compared notes and discovered one good bombsight (the Navy's Nor-

DAN PATTERSON

The bombardier had to concentrate on his sight—despite the distractions of flak and fighters.

den Mark XV design) and one promising autopilot (the Army's Sperry A-1). More than a decade of interservice squabbling would pass before the twain would truly meet for the common cause. Until then the Army had to procure all its Nordens through the Navy, a situation that surely must have rankled.

After agreeing to work for the Navy, Norden sought refuge at his mother's Zurich home to design his Mark XV bombsight. When he returned in 1930 to demonstrate a prototype, Lieutenant Frederick Entwistle, the Navy's chief of bombsight development, judged it revolutionary. The most significant improvement was that the new design was synchronous. One simple adjustment by the bombardier simultaneously measured the aircraft's ground speed and locked the target under the sight's horizontal crosshair. Norden's marvel of ingenuity also provided true air speed, wind speed, wind direction, and angle of drift. It automatically dropped the bomb load at the right instant, eliminating a significant source of human error. (Germany also developed a synchronous bombsight during World War II but lacked the aircraft and training to make it useful. Japan made do with much cruder equipment.)

Veteran bombardiers at the Navy's proving ground found they could set the new bombsight in six seconds versus the 50 seconds needed for the previous Norden model. In tests involving 80 bomb drops, half landed within 75 feet of the target. Production models proved to be significantly more accurate. This intricate 50-pound collection of gyros, motors, gears, mirrors, and levers was beyond doubt the finest optical bombsight ever invented. Patents were assigned to the Navy and concealed from prying eyes until 1948.

The Norden bombsight that the Navy called Mark XV was called the M-series by the Army. Containing some 2,000 precision parts, it was a marvelously complex machine that was continually refined during World War II. By war's end nearly 90,000 bombsights had been constructed by Norden and other contractors at a cost of $1.1 billion to the U.S. government.

With production bombsights in hand, the Army Air Corps finally had an opportunity to rehearse daylight precision strategic bombing. Practice did not make perfect. Brigadier General H. H. "Hap" Arnold (later commander of the Army Air Forces) plotted the progress of one of his bomb groups in 1935: "From 15,000 feet, we began on the first day by placing eggs within 520 feet of the target, closing the gap to 480 feet at the end of seven days, to 300 feet at the end of 27 days, and placing its bombs regularly within 164 feet of a target no bigger than a woodshed at the end of 41 days. If airmen got to talking a little too confidently about tossing it right in the pickle barrel, our continued improvement in bombing with the Norden sight may explain why."

McFarland notes that close enough may count in horseshoes but not with bombs. A 2,000-pounder—the largest in Army inventory before the war—blew a crater 50 feet in di-

Carl L. Norden (opposite) worked at the Sperry Gyroscope Company before designing his own bombsight.

Theodore Barth (third from right, visiting a component factory) was an ideal business partner for Norden.

Oct. 7, 1947. C. L. NORDEN ET AL 2,428,678

BOMB SIGHT

Filed May 27, 1930 11 Sheets-Sheet 7

Fig. 13

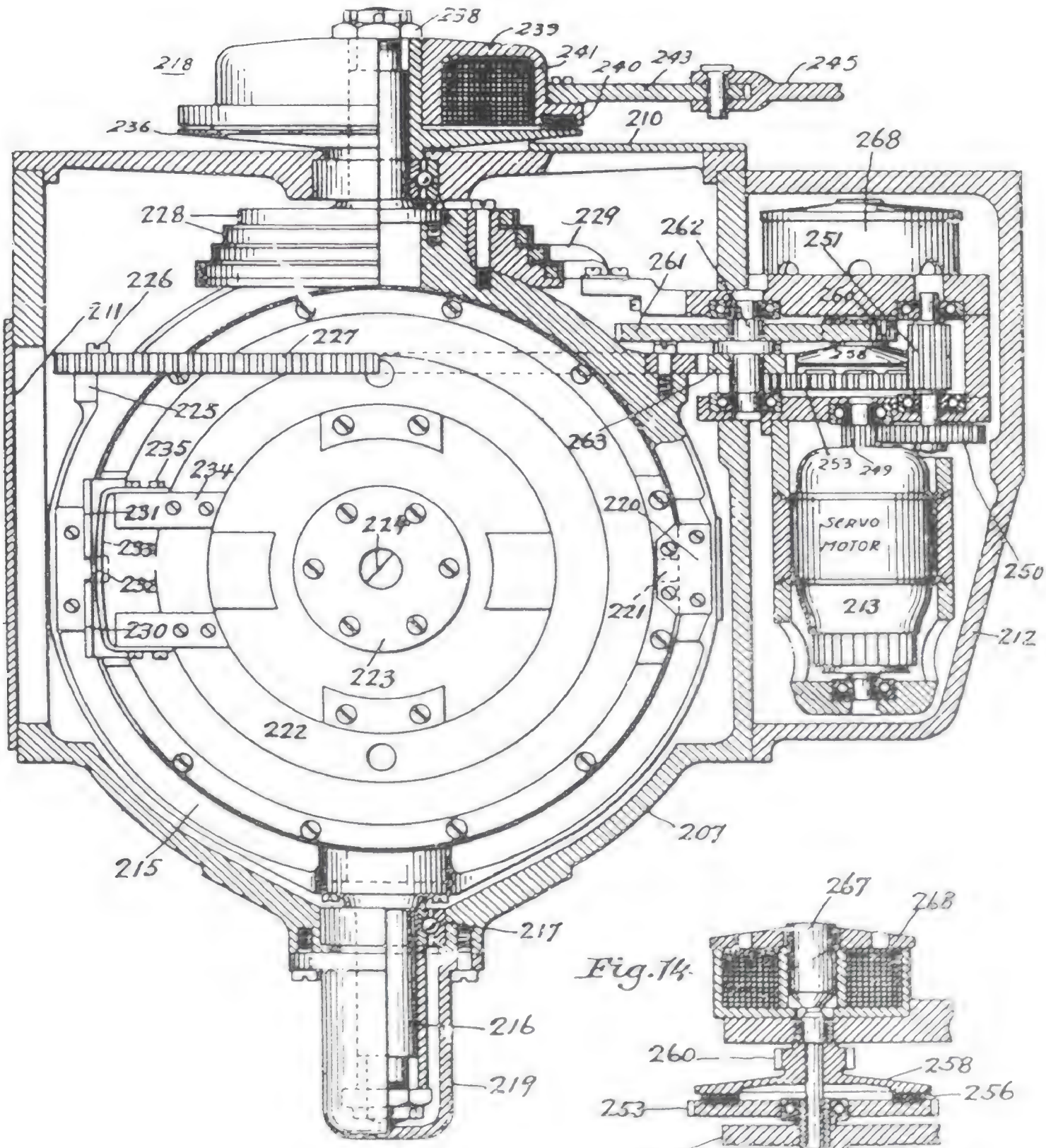
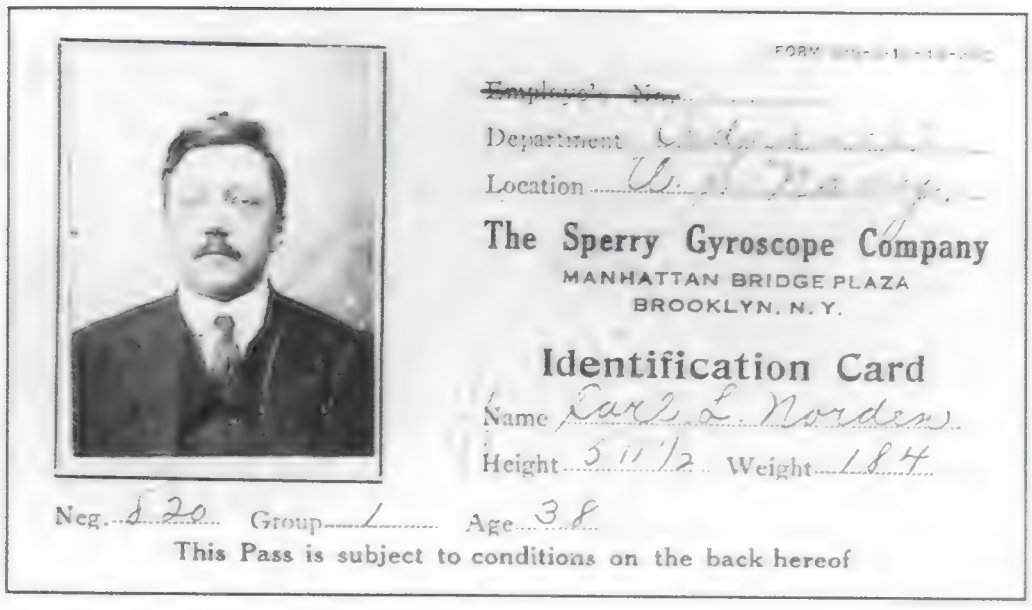


Fig. 14

Inventors
CARL L. NORDEN
THEODORE H. BARTH

BY Harold Todd
ATTORNEY



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Location

The Sperry Gyroscope Company
MANHATTAN BRIDGE PLAZA
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Identification Card

Name Carl L. Norden

Height 5 11 1/2 Weight 184

Neg. 120 Group 1 Age 38

This Pass is subject to conditions on the back hereof

RICHARD NOWITZ

The atomic bomb was a weapon of mass destruction, not pinpoint precision, yet bombardier Thomas Ferebee in the Enola Gay *used a Norden sight to drop the "Little Boy" bomb on Hiroshima.*

ameter and had a maximum effective fragmentation range of 125 feet. During the 1930s higher speeds and altitudes were needed to escape the reach of defensive anti-aircraft artillery, which only diminished accuracy. Planners concluded that using a larger number of smaller bombs was necessary to increase the chances of striking a target. The 500-pound bomb was selected as the optimum, and 40-bomber formations were specified.

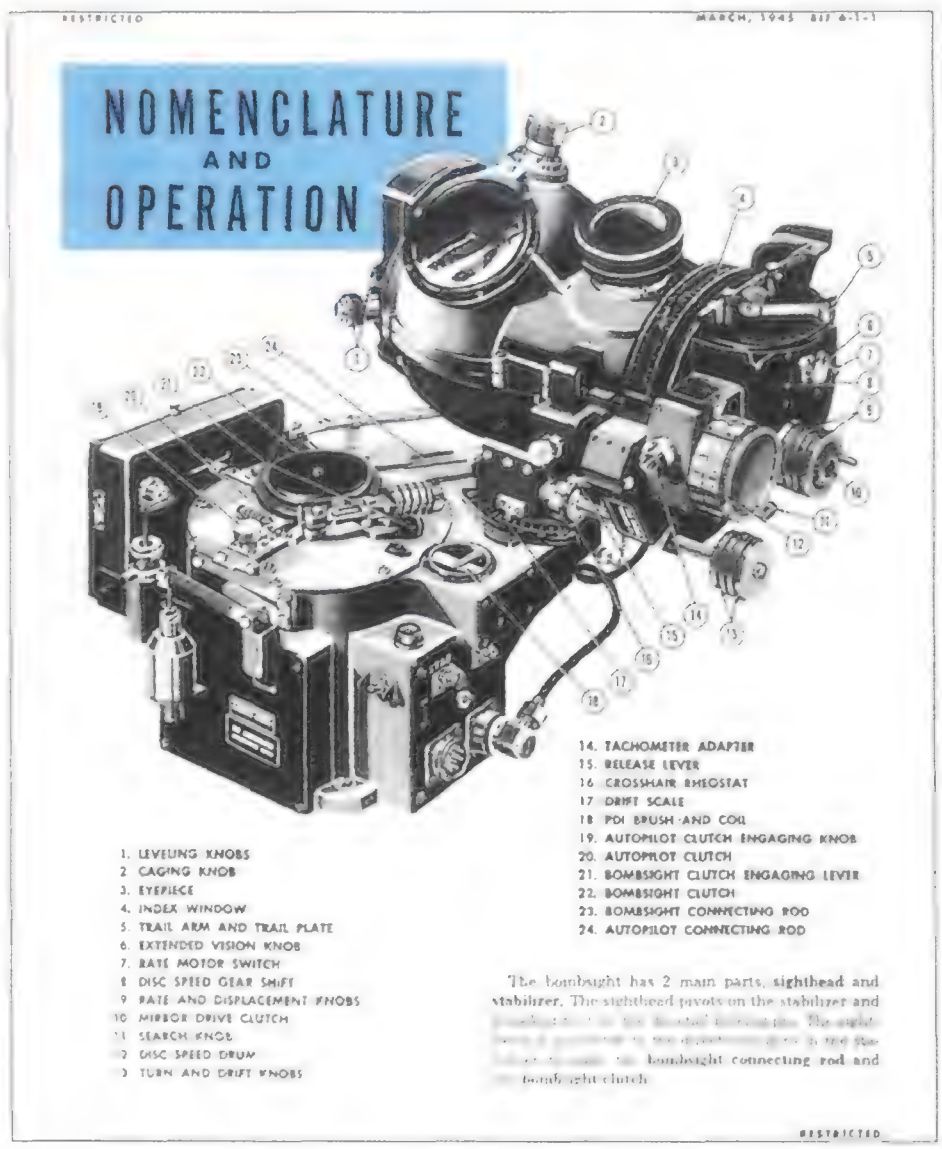
The vision of striking the enemy with frontier marksmanship gradually evolved into a shotgun approach. Still, on the eve of World War II the ever-optimistic Barth postulated, "We do not regard a fifteen foot square...as being a 'very difficult' target to hit from an altitude of 30,000 feet, provided the new Army M-4 bombsight, together with Stabilized Bombing Approach Equipment is used." (Norden designed and developed his Stabilized Bombing Approach Equipment—SBAE—during the 1930s. In 1941, Minneapolis-Honeywell incorporated some SBAE components into its C-1 electronic autopilot, which became a mainstay for World War II aviation.)

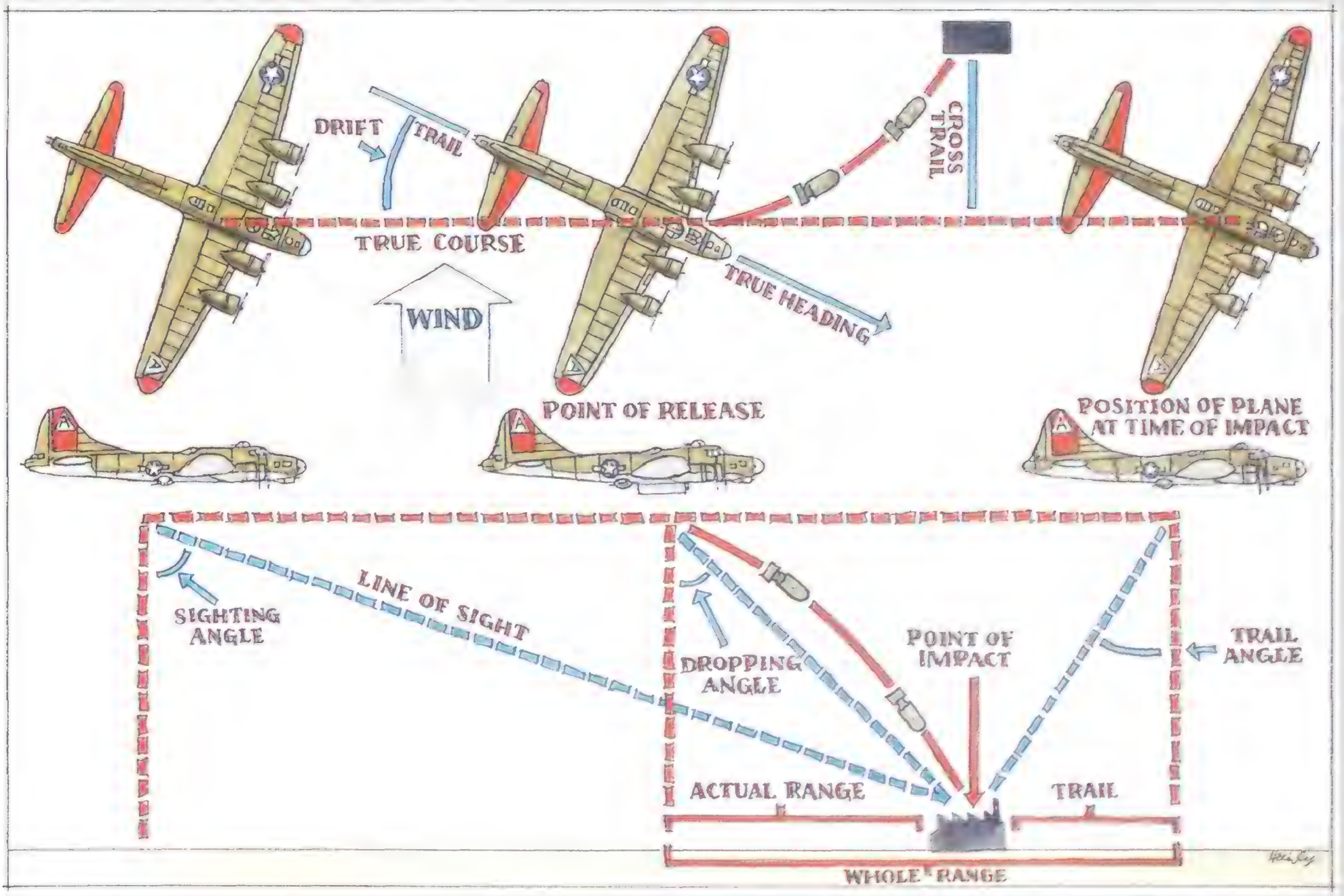
Procurement became a big headache because the Navy, having spent a decade developing the bombsight, was not inclined to share its production with the Army. When an Army colonel first knocked on Norden's door for help after World War I, the designer's response was, "No man can serve the Lord and the Devil at the same time—and I work for the Navy." Norden regarded Navy officers as patrician gentlemen and Army officers as plebeians. Years later, Air Corps chief Foulois secretly attempted to negotiate a contract with Barth, but Barth insisted he was morally bound to sell all Norden bombsights to the Navy. It would be up to the Navy to provide them to the Army, if it chose to do so.

The conversion of Carl L. Norden, Incorporated, from an engineering lab to a production factory was a major undertaking. Before the outbreak of hostilities, skilled craftsmen—most of them German or Italian immigrants—hand-made practically every part of what amounted to an oversize Swiss watch. Hundreds of ball bearings had to be ground and polished for each bombsight. Norden himself inspected every piece. Between 1932 and 1938, the company produced only 121 bombsights per year, far short of demand.

During the first year after Pearl Harbor, Norden produced only 6,900 bombsights, three-quarters of which went to the Navy. Expanding production to the final total of six factories proceeded at an agonizing pace. When the Navy refused to allow U.S. allies to use the Norden sight, the Army was forced to ship lend-lease bombers with obsolete alternatives. Infuriated with Navy bureaucracy, the Army received permission from the war department to contract with Victor Adding Machine to build Norden bombsights and with Sperry to manufacture its own design.

Eventually production caught up with demand. The Navy admitted that it really didn't need Norden sights because it had chosen dive bombing as its preferred means of attack. Army strategies had changed as well: since entire bomber formations were salvoing their loads on cue from a lead bombardier, it wasn't necessary for every airplane to be equipped with a bombsight.





The Bombardier's Computer

In order to hit a target, a bombardier would "program" his Norden bombsight to select the correct flight path and determine when to release the bombs.

The lower portion of the Norden sight, called the stabilizer, is rigidly mounted to the aircraft. It contains a gyro spinning at 7,800 rpm to provide yaw stability.

The removable sighthead, also known as the football, is mounted above the right-front corner of the stabilizer. It contains a gyro for roll and pitch stabilization, a motorized optical system, an index scale with two pointers (indicating dropping and sighting angles), electrical contacts that trigger bomb release, and various adjustment knobs and levers. A spinning disk inside the sighthead drives both the optical system and the sighting angle indicator. The sight itself flies the aircraft on its final run and drops the bombs.

In preparation for a bomb run, the bombardier conducts several equipment checks and energizes the gyros. Range—the distance from the target when the bombs will be dropped—is the first problem the bombardier solves. Two key pieces of information he must program into the sight are the bomb's actual time of fall (ATF) and its trail. ATF depends on altitude and the bomb's aerodynamic characteristics; it is measured in field tests and provided to the bombardier in reference tables. Trail is the amount of forward momentum that the bomb loses upon release and also depends on altitude and the bomb's air resistance.

By adjusting concentric rate and displacement knobs, the bombardier positions the target under a horizontal crosshair. The resulting rate setting corresponds to the airplane's ground speed. Engaging the mirror drive clutch keeps the horizontal crosshair fixed on the target.

Before solving the course problem, the bombardier levels the bombsight and "uncages"—unlocks—the vertical gyro. Simultaneous adjustment of the drift and turn knobs sets the airplane's drift angle—which compensates for crosswind—and lines up the bombardier's line of sight to the target. When the bombardier splits the target with the vertical crosshair in the bombsight's 2.2-power telescope, the airplane is on a course capable of delivering bombs to the target.

To the right of the bombsight's telescope is a quadrant displaying two pointers on an index scale. The right pointer indicates the dropping angle, calculated by the sight. The left pointer moves as the sighting angle between the aircraft and the target decreases. When the left pointer aligns with the right pointer, electrical contacts automatically close to release the bombs.

Accurate bombing was complicated by the aerodynamic forces acting on the projectile and airplane. The Norden sight, a complex mechanism of gears, gyros, motors, and knobs (opposite), compensated for factors like wind and drift and, coupled to the autopilot, flew the bomber to the proper release point.

With his instructor looking over his shoulder, a bombardier-in-training learns the complexities of a Norden (below). Mastering the sight was no easy task and required close study of the manuals (left).

After investing more than $100 million in Sperry bombsight manufacturing, the Army Air Forces concluded that the Norden M-series sight was far superior in accuracy, dependability, and operational design. Sperry contracts were canceled in November 1943. When production ended a few months later, 5,563 Sperry bombsight-autopilot combinations had been built, most of which were installed in B-24 Liberator bombers.

The war years were very good to Carl L. Norden, Incorporated. The company and its subcontractors produced 72,000 M-9 bombsights costing $8,800 apiece for the Army Air Forces. Norden executives ate at an exclusive Pickle Barrel Conference Club established by Barth on the second floor of the firm's Manhattan headquarters at 80 Lafayette Street. Napkins were decorated with a whimsical crest showing smiling bombs plunging into a pickle barrel and a Latin motto that, loosely translated, boasted "Let a better pickle barrel be made in the future and it will perish at Norden's hand."

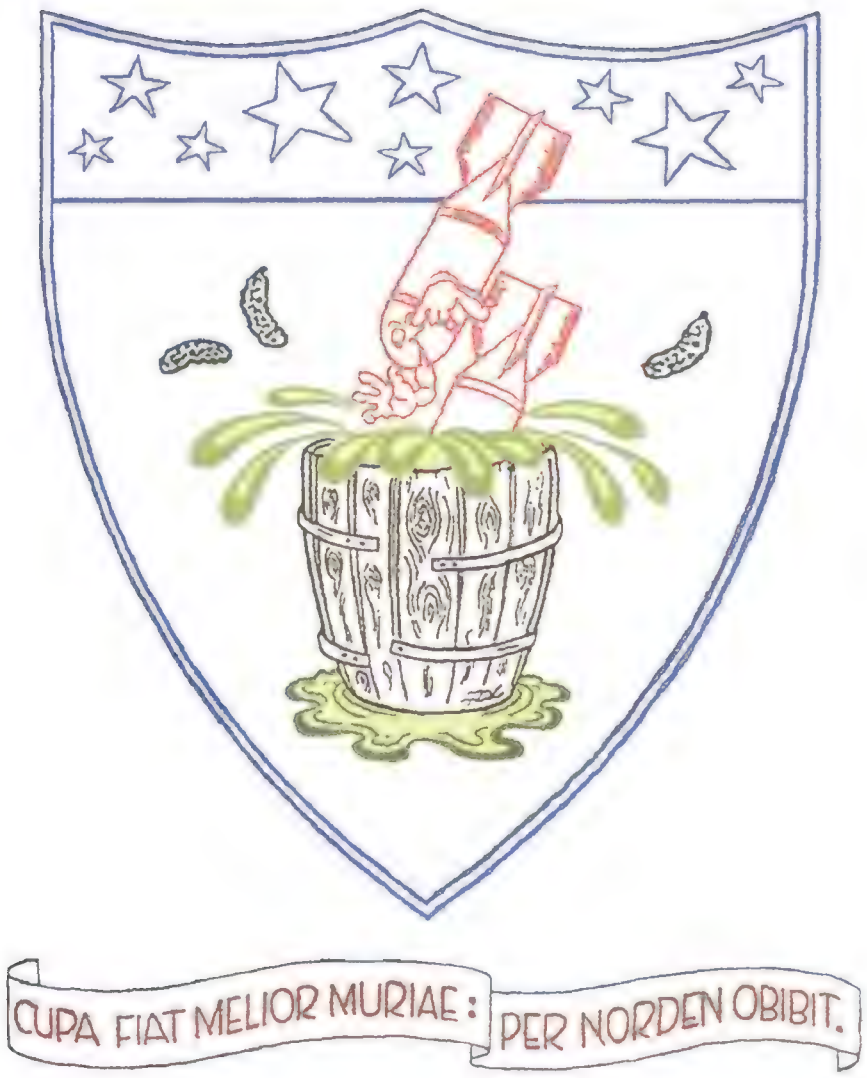
Except for lunch with 30 or so of his top executives, the reclusive Norden seldom left the sanctity of his drafting board. In sharp contrast, Barth was fun-loving and gregarious. When waiters brought dessert, he often declared, "My, that's a good throwing pie!" After the firm won its third Army-Navy "E" award for excellence, Barth rented Madison Square Garden and hired the Ringling Brothers Circus to entertain employees, their families, and the firm's military clients.

While Norden executives dined, their bombsights went off to war under a well-publicized campaign of secrecy. Its security classification, however, had been reduced from "secret" to "confidential" in 1935 and from "confidential" to "restricted" in 1942 to facilitate production and use. According to an Army Air Forces announcement in 1943, "there was no cause for alarm if the Axis captured bombsights because Axis scientists would require at least two years to duplicate the device." Nonetheless, bombardiers took an oath to keep their instrument from enemy hands—if need be, sacrificing their lives—and had orders to use a .45-caliber handgun to destroy it in the event their aircraft was forced down.

The Army Air Forces tapped novelist John Steinbeck to write a recruitment documentary, *Bombs Away*, in which he noted, "The bombsight has become the symbol of responsibility. It is never left unguarded for a moment. On the ground, it is kept in a safe and under constant guard. It is taken out of its safe only by a bombardier on a mission, and he never leaves it. He is responsible not only for its safety but its secrecy. Should his ship be shot down, he's taught how quickly and effectively to destroy it." Hollywood did its part in the 1943 epic *Bombardier*, a film that exalted the deadly accuracy of the Norden sight and the courage of the bombardier who hunched over it like a diamond cutter, without divulging so much as a glimpse of the actual instrument.

Was it all prudent security precautions, or a morale-boosting propaganda ploy? "A lot of it was hype, just like the pickle barrel precision," says Carroll Watkins, who maintained Nordens for the Sixth Air Force during the war and refurbishes them for museums today. "No bombsight ever had that and never will. You couldn't even see a pickle barrel from 20,000 feet."

NASM



Bombs did hit the pickle barrel, at least in the logo adorning the menus at Norden headquarters.

Yet Watkins found much to admire in the Norden. "I was fascinated by it," he says. "It was such a precise device. It was built like a precision watch. I was amazed at the close tolerances used in the equipment."

Admirable as the instrument may have been, the actual conditions of wartime flying quickly forced an increase in the size of the pickle barrel. During the latter months of 1942 only five percent of the Eighth Air Force's bombs fell within 1,000 feet of the aiming point. In actual wartime conditions, staunch German defenses forced bombers to fly higher and in larger but more tightly packed formations. Smoke screens, industrial haze, and clouds obscured targets and frustrated navigation. In the heat of battle, crews inevitably made mistakes. Every flak cannon added to the error.

Crouched in the plexiglass nose of the aircraft, bombardiers had the worst seat in the house. Breathing pure oxygen in temperatures of 40 below, their ears ringing with thousands of horsepower generated by hundreds of pistons, they had to adjust their bombsights—wearing silk gloves so their fingers wouldn't freeze to the frigid metal—even as their airplanes flew through thick flak and withstood attack from enemy fighters. On their shoulders weighed the responsibility for the success of the entire mission.

Lloyd Johnson, today an Ann Arbor, Michigan businessman, flew eight combat missions aboard an Eighth Air Force B-17 during 1945. Unlike many bombardiers, Johnson never wanted to be a pilot; he chose his post after seeing the film *Bombardier*. "I wanted to win the war all alone as a lead bombardier in the Eighth Air Force," he says. "I listed my duty preferences with the recruiter in this order: bombardier, navigator, aerial gunner, ground crew, and pilot."

As a bombardier, Johnson found the Norden to be an excellent tool. "I have such great respect for the instrument," he says, "because properly used and with the proper information fed into it, it was tremendously accurate." To speed up the aiming procedure, Johnson began memorizing his bombing tables as he ate in the mess hall, which earned him the nickname "Professor." Because the sight essentially flew the airplane on the final run, late adjustments could result in a missed target. "If you were still cranking in a last-minute correction and the plane was in a slight tilt or bank, it would throw the bombs off a long way," says Johnson.

Charles Hudson, a bombardier who flew 37 missions for the Eighth Air Force, was another dedicated student of the Norden bombsight. "I used to work at that thing all the time," he says. "At our base in England I had them take the bombsight apart so I could inspect and understand all the little instruments inside.

"I trusted and believed in that sight," he continues. "It was an excellent piece of equipment. What always amazed me was the sight of bombs dropping out of the plane at what looked like a 45-degree angle [due to crosswinds]. But all that was figured into the bombsight settings.

"I would set everything up in advance. After the initial point, once I was on the right heading I'd start making little S-turns to evade the flak guns: 10 seconds to the left, 20 seconds to the right, at about five degrees. Often times I had my head down while the crew was firing machine guns. It was hard to keep your eye on the bombsight with the whole ship shaking. But as I told the other bombardiers, it's vital not to look up during the last 40 seconds to the target."

Thanks to dedicated bombardiers like Hudson, accuracy did improve with experience. However, real precision bombing was seldom achieved. Instead of a few sharpshooters, the Army Air Forces mustered vast armadas—up to 2,000 B-17 and B-24 bombers per mission—to darken the sky over Germany, bludgeoning the enemy by saturating target areas with 500-pound bombs. Except in the final month of bombing—April 1945—more than half the bombs dropped landed more than 1,000 feet from their targets. All told, less than one-third landed within 1,000 feet of the aiming point. Against Japan, the daylight precision strategic bombing record was only slightly better, prompting a shift toward area bombing, which finally turned the tide.

Neither the Norden bombsight nor the men who used it deserve blame. Fault lies with the precision strategic bombing doctrine. Even today, nearly 50 years after the war's end, there is spirited discussion about the merits of strategic bombing, but it is clear that the Army Air Forces didn't have the accuracy it presumed, its bombers couldn't always defend themselves adequately, and the enemy was not as readily deprived of war materiel as Allied planners had hoped. Though the doctrine was fundamentally flawed, the bomb crews still bravely flew their missions, the bombardiers crouched over their secret weapons and aiming at the pickle barrel.


BUD ONE
CAN TRS

>SIGHTINGS<

PHOTO: PETER B. KAPLAN

Perhaps it's just their size, but blimps are wonderfully photogenic, whether in the air or on the ground. To obtain his shot of the Anheuser-Busch *Bud 1* over Philadelphia during the 1993 National League baseball playoffs, photographer Peter B. Kaplan attached his remote camera to the blimp's radar rigging. Strobes were used to light the gondola's interior. The result, while spectacular, is not something many people would want to experience first-hand.

In Kaplan's photo above, Goodyear's *Spirit of Akron* retires for the night at its Pompano Beach, California maintenance facilities. Blimps may be a sight to behold in the sky, but they can be equally overwhelming under a roof.

"Hey, We've Got a Problem Here."

ARCHIVE PHOTOS

Fred Haise, Jim Lovell, and Jack Swigert wait for pickup in a rubber raft.

Lost Moon: The Perilous Voyage of Apollo 13 *by Jim Lovell and Jeffrey Kluger. Houghton Mifflin, 1994. 378 pp., b&w photos, $22.95 (hardcover).*

In the course of reading two other Apollo anniversary books (*Moon Shot* and *A Man on the Moon*), I was struck by the realization that Apollo 13 was the real climax of our lunar epic. Not the political climax, which was Apollo 11, nor the scientific anticlimax, which unfolded in the last four missions, but the dramatic, human climax. For it was Apollo 13 that finally served up the onboard explosions, the desperate maneuvers, the failing life support systems—in short, the nightmare scenario that had always threatened manned spaceflight, making it irresistible to the public but maddening for NASA, the astronauts' families, and indeed the whole nation. That is one reason why all students of space history ought to read this thrilling log even if they think they know the tale of unlucky 13. Another reason is that *Lost Moon* combines thorough research into all the events surrounding the mission, including those back in Houston, in network newsrooms, and in the offices of harried aerospace contractors, with the personal account of astronaut Lovell aboard the stricken spacecraft. The result is fine scholarly work and an outstanding memoir.

Suspense, skillfully understated, emerges naturally from the narrative. Since the authors are faithful to the chronology and eschew the omniscience of hindsight, the reader discovers along with NASA and the crew just what damage Apollo 13's service module *Odyssey* has sustained, and what maneuvers *might* succeed in nursing the astronauts home. And only after journey's end, when the Cortright Commission issues its report, do we learn that the emergency was caused by an oxygen tank in the service module that exploded on the way to the moon.

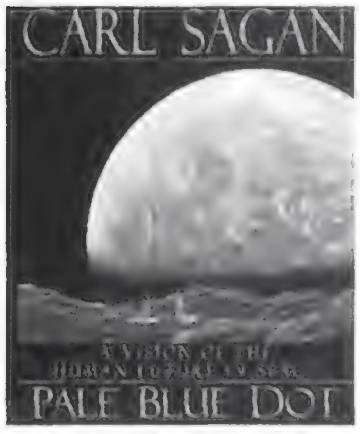
The only ingredient that could have been provided more liberally is human pathos. Reading between the lines, one gets the sense that journalist Kluger yearned to elaborate on the ordeal of the three men squeezed for days into the lunar module with barely enough heat, oxygen, and water to sustain life, but that Lovell, ever the professional, forbade the writer to dwell on the crew's suffering and courage.

Perhaps. But there is no question that the main theme of the book is death. The book's first sentence explodes the myth that astronauts were issued poison pills in case they were marooned in orbit. The book reminds us serially of other deaths, such as those of Gus Grissom, Ed White, and Roger Chafee in the Apollo 1 fire on the pad: "an earthbound death was to be envied least of all." The book's most endearing "right stuff" is displayed by Marilyn Lovell, misinformed by science reporter Jules Bergman that her husband's crew had only one chance in ten of getting home alive, and chasing away ghoulish reporters eager to set up a death watch on her lawn. And the book's philosophical apogee is surely the pre-launch interview in which Bergman presses Lovell to talk about fear and contrast the risks an astronaut takes with those of an F-4 pilot in Vietnam. "Going to the moon and using the systems we use is risky," replied Lovell in an even tone. "But we use the best technology we have to minimize that risk. When you go into combat, the other side is using the best technology they have to *maximize* your risk. Obviously, I think that's a very dangerous proposition." A wise and humble insight—but the fact remained that the fate of Apollo 13's three men, caught in a can that sprang a leak halfway to the moon, was a matter of concern to every American. A pilot downed over Vietnam in the spring of 1970, on the other hand, was little more than a stat. Such ironic juxtapositions, which abound in *Lost Moon*, tell us as much about ourselves as about NASA's "systems"—human and otherwise.

—Walter A. McDougall is the author of The Heavens and the Earth: A Political History of the Space Age, *which won a Pulitzer Prize in 1986.*

Pale Blue Dot: A Vision of the Human Future in Space *by Carl Sagan. Random House, 1994. 429 pp., color and b&w photos, $35.00 (hardcover).*

"It's time to hit the road again," writes Carl Sagan in *Pale Blue Dot*, and coming from the man who brought us the hugely



popular *Cosmos* (both a book and television series), you know he's not talking about a weekend getaway. Travel is broadening, according to Sagan, but ultimately he believes that settlements in space must be established to prevent our extinction.

Pale Blue Dot is really two books: it's a primer on modern planetary science and also a philosophical examination of our urge to explore space. In its early chapters, the book has the ambiance of an old-fashioned salon, where Galileo, Einstein, and others hold forth.

Along the way Sagan dabbles briefly in metaphysics, suggesting that the day might arrive when humans will have the tools to peer into adjacent universes. The link between science and the soul has become a popular theme for writers from Stephen J. Hawking (*A Brief History of Time*) to Gary Zukav (*The Dancing Wu Li Masters*), and Sagan carries the torch a bit further.

Unlike many of his contemporaries, Sagan refuses to treat space exploration as history. He also doesn't shrink from controversial topics like the greenhouse effect (which he believes in) and Star Wars defense strategies (which he detests). And then there's NASA. The space agency in the last few years has been asleep at the wheel, Sagan notes, but he defends its work with robotic probes.

Sagan concludes that human space exploration is affordable—even inexpensive, considering that our survival is at stake. Sooner or later he predicts a giant asteroid or comet will slam into Earth and wipe out most traces of life. His solution is to settle space.

The lavish illustrations are almost reason enough to buy this book. Yet ultimately it's the celebrity astronomer's gift for converting a complex subject into entertainment without shortchanging the science that distinguishes the book. Sagan, who turned 60 last year, now ranks as a senior statesman for the universe. *Pale Blue Dot* happily supports this reputation.

—Theresa Foley is the former editor of Space News.

CD-ROMs

The compact discs that made your record albums obsolete also hold words and pictures, and an increasing selection of space-related titles is available. Some simply serve up widely available NASA images, while others feature original computer animation. A partial list appears below (manufacturers' names are in parentheses). For more information, visit your local retailer.

Americans in Space (Multicom) presents a history of U.S. manned spaceflight.

Buzz Aldrin's Race Into Space (Interplay) lets users compete in a race to the moon as mission directors for the United States and the former Soviet Union.

Expert Astronomer (Expert Software) is a multi-media planetarium program with over 9,000 celestial objects in its database.

Journey to the Planets (Multicom) uses computer animation to take users on a ride over planetary surfaces.

Mars Book (Human Code) offers an animated tour of the proposed Mars Habitat.

Mission: Planet Earth (Lunar Eclipse Software) includes photos of Earth taken by astronauts, as well as a geography quiz.

Planetary Taxi (Voyager) lets users learn about astronomy by hailing taxi rides around the solar system.

RedShift (Maris) is a home planetarium that offers a view of any place and time in the universe during the last 15,000 years.

Return to the Moon (Lunar Eclipse Software) features a moonflight simulator and an electronic lunar atlas that includes photos, videos, and sound clips related to lunar exploration.

Small Blue Planet (Now What) is an up-to-date world atlas, including photo-mosaics of continents and U.S. Geological Survey aerial views of 64 U.S. cities.

Space (Sumeria) bills itself as "a visual history of manned spaceflight" and includes 90 minutes of video from the Mercury, Gemini, Apollo, and shuttle missions.

Space & Astronomy (Walnut Creek) offers a grab bag of NASA images and includes such details as Wally Schirra's Boy Scout rank.

Space Shuttle (Software Toolworks) features extensive film footage of 53 shuttle missions.

Space Simulator (Microsoft) transports users into the cockpit of an interstellar spacecraft that travels to the far ends of the galaxy with realistic graphics and sound effects.

Star Trek: 25th Anniversary (MacPlay) allows users to assume the role of Captain Kirk as he steers the USS *Enterprise* and its crew around the galaxy.

The View From Earth (Time Warner) offers a slide show and guided tour of our planet.

—Richard Sassaman is a freelance writer in Bar Harbor, Maine.

Peenemünde and the Coming of the Ballistic Missile Era *by Michael J. Neufeld. Free Press, 1994. 368 pp., b&w photos, $25.00 (hardcover).*

This book is about facts and myths. The facts are that between 1932 and 1945, the German government supported the development and deployment of a series of missile weapons, the most important of which was the V-2 ballistic missile. In a brilliant research and development program, technical director Wernher von Braun and his colleagues fielded a weapon that could carry a one-ton warhead about 200 miles and land it within 12 miles or so of its target. In 1944 and 1945, about 3,200 of these weapons were fired at Britain and Belgium, but they had no significant impact on the outcome of World War II.

The myth of V-2 development is that von Braun and his associates were dreamers who duped the German army into supporting a program that was really designed to achieve spaceflight. That they used the Nazi state but remained unsullied by it, innocent of the political and humanitarian horrors of National Socialism. That von Braun was even imprisoned for a while for disloyalty, and that when the chance came late in the war, he and his friends fled to embrace the invading Americans.

This book, based primarily on research into previously untapped archives, makes clear that von Braun and his team overlooked the horrors about them in order to achieve not spaceflight but the rewards that would shower upon the makers of a war-winning weapon. Von Braun was imprisoned not for disloyalty but rather as a result of a cynical ploy by Heinrich Himmler to gain control of the rocket program. The rocket group did not

seek out the Americans but rather was swept along by events beyond its control.

Author Michael Neufeld, a curator at the National Air and Space Museum, finds no smoking gun that directly links von Braun to the slave labor camp of the infamous *Mittelwerk* underground factory where the V-2s were produced after bombing raids on Peenemünde. But he does make clear that von Braun knew what was going on and made no effort to stop it. The telling fact about this misguided project is that more people died producing the V-2 than were killed in its attacks.

—Alex Roland is a professor of history at Duke University.

CURATOR'S CHOICE

Airways: The History of Commercial Aviation in the United States *by Henry Ladd Smith. Smithsonian Institution Press, 1991. 448 pp., $19.95 (paperback).*

Henry Ladd Smith's classic 1942 history, available as a reprint, is the seminal work on the formative years of U.S. air transportation. Though over 50 years have elapsed since its original publication, this extremely valuable and well-written work remains the best single-volume treatment of the subject.

—F. Robert van der Linden is curator of the air transport collection at the National Air and Space Museum.

Voyage to the Great Attractor: Exploring Intergalactic Space *by Alan Dressler. Knopf, 1994. 355 pp., b&w photos, $25.00 (hardcover).*

It was a classic case of serendipity. In 1980, a group of seven astronomers from the United States and England set out on a painstaking but comparatively straightforward survey to measure the distance to elliptical galaxies so that they (and others) could make better maps of these galaxies' distribution in space.

In January 1986, however, when the group finally reported their results, their conclusions were astounding even by astronomical standards. In effect, they found that our galaxy and most others for hundreds of millions of light-years in every direction are streaming together toward a certain point in the southern sky at some 600 kilometers per second—

roughly a thousand times faster than a rifle bullet.

The announcement galvanized cosmologists everywhere. The cause of these peculiar motions—presumably a vast and previously unknown clump of matter that is perturbing the local universe through its gravity—was quickly dubbed the Great Attractor. The seven astronomers who had performed the survey were dubbed, even more quickly, the Seven Samurai. Follow-up observations soon showed that the Great Attractor is real: marked by a huge collection of galaxies roughly 200 million light-years from Earth, it is so broad and diffuse that no one had noticed it before. Still other observations turned up hints of similar mass concentrations elsewhere in the universe, at much greater distances. And the questions have raged ever since. How did the Great Attractor form? How does it manage to exert such an enormous gravitational pull? (The total mass of all the visible galaxies in the Great Attractor isn't nearly enough to explain it.) Is there some sort of invisible "dark matter" that underlies the Great Attractor? And if so, what is it?

The opinions are many, and the answers so far are few. The one thing that everyone agrees on is that the work of the Seven Samurai is one of the landmark events in modern cosmology. *Voyage to the Great Attractor*, by Samurai team member Alan Dressler, is a memoir of their collaboration. Casual readers should be warned: in astronomy, more than in most sciences, the devil is in the details. And Dressler does nothing to gloss this over. Quite the opposite: much of the drama and tension in the Seven Samurai story are driven by the arcane grubwork of instrument calibration, data reduction, and statistical analysis. Are the numbers really telling us what they seem to be telling us? Or are we going to be horribly embarrassed by some observational error that none of us even noticed?

Nonetheless, readers who persevere will be rewarded with a gracefully told and heartfelt story of seven very human people doggedly pursuing the passion to understand the universe. This is how great science really takes place. And Dressler shows us what it was like to be there.

—M. Mitchell Waldrop is the author of Complexity: The Emerging Science at the Edge of Order and Chaos *(Simon & Schuster, 1992).*

CREDITS

The Big Creek Missile Agency. Homer H. Hickam Jr. is the space station payload training manager at Marshall Space Flight Center in Huntsville, Alabama. His last piece for this magazine, "Coming to America," appeared in the Aug./Sept. 1994 issue.

Speech Lesson. Since World War II, Arnold Benson has been writing ad copy in New York. He has written short stories, essays, and features for *Esquire*, the *New York Times*, and *Sports Illustrated*. His only pilot-in-command flight after the war was flying a load of clams to a clambake in New York State.

Something Gold, Something New. Phil Scott is a freelance writer based in New York City. His first book, *The Shoulders of Giants: A History of Human Flight to 1919*, will be published this spring by Addison-Wesley.

Further reading: *The Great Air Races*, Don Vorderman, Bantam Books, 1989.

Heavens on Earth. Bennett Daviss is a journalist who reports on science and technology for several national publications.

The Race to Save Rwanda. Stephen F. Vogel, who lives in Bonn, Germany, is a correspondent for the *Washington Post*.

The X-Hunters. Lance Thompson writes on aviation topics from Sun Valley, California. He is currently working on a screenplay about Bessie Coleman, the first black female pilot.

Mission to Mir. Tom Harpole is a frequent contributor to *Air & Space/ Smithsonian*.

The Awe-Ja-Magic Fly-In Pancake Breakfast. Stephan Wilkinson is a contributing editor of *Air & Space/ Smithsonian*. This is the third installment in a series about his homebuilt Falco.

Six Ways Back to NASA Greatness. Illustrator Alan E. Cober, a recipient of 10 medals from the Society of Illustrators, will be the regular artist for "Commentary." A professor of art at the State University of New York at Buffalo, he will be the artist-in-residence at the Ringling School of Art in Sarasota, Florida, this spring.

The Secret Weapon. Educated as a mechanical engineer, Don Sherman was awed by the ingenious complexity of the Norden bombsight. The Belleville, Michigan writer admits the story was a refreshing change of pace from his usual activity: reviewing cars for *Motor Trend* and *Popular Science*.

America's Pursuit of Precision Bombing, an exhaustively researched chronicle by Auburn University professor Stephen McFarland, was a primary source of information for this story. It will be published this spring by Smithsonian Institution Press.

Shrine of the Flying Saucer. Austin, Texas freelancer Damond Benningfield writes and produces the syndicated radio program "Star Date."

CALENDAR

February 12
Second Air Division, Eighth Air Force Reunion. Clarion Plaza Hotel, Orlando, FL, (407) 352-9700.

February 19 & March 19
Open Cockpit Sunday. New England Air Museum, Bradley International Airport, Windsor Locks, CT, (203) 623-3305.

March 2–4
Pilots & Poster Girls, a symposium commemorating the 50th anniversary of World War II. Sponsored by the Confederate Air Force. Midland, TX, (915) 685-4641.

March 5–8
Upper Midwest Aviation Symposium. Sponsored by the North Dakota Aviation Council. Radisson Inn, Bismarck, ND, (701) 224-2748.

March 11 & 12
Delight of Flight Airshow and Fly-In. Saint Lucie County International Airport, Fort Pierce, FL, (407) 461-0346.

March 17–19
Valiant Air Command Airshow. Space Center Executive Airport, Titusville, FL, (407) 268-1941.

March 18 & 19
Wings of Victory Airshow. Confederate Air Force air power demonstration. Phoenix Goodyear Airport, Phoenix, AZ, (602) 924-1940.

"The Satellite Sky" Update/46

These regular updates to "The Satellite Sky" chart will enable readers to keep their charts up to date. Additions can be clipped and affixed to the chart at the appropriate altitude.

New launches

90 to 300 MILES

- Cosmos 2293 11-2-94 TT
- Progress M-25 11-11-94 TT

300 to 630 MILES

- Okean 4 10-11-94 PL
- IRS-P2 10-15-94 ISRO
- Resurs-01 11-4-94 TT
- Safir-R 11-4-94 TT
- Cosmos 2297 11-24-94 TT

630 to 1,250 MILES

- Elekon 1 11-29-94 PL

6,200 to 13,700 MILES

- Cosmos 2294-96 11-20-94 TT

21,750 to 22,370 MILES

- Intelsat 7 F3 10-6-94 CAC
- Solidaridad 2 10-8-94 KOU
- Thaicom 2 10-8-94 KOU
- Express 1 10-12-94 TT
- Elektro 1 10-31-94 TT
- Astra 1D 11-1-94 KOU
- Orion 1 11-28-94 CAC

Deletions

90 to 300 MILES

Cosmos 2284 down 9-11-94

Progress M-24 down 10-4-94

Soyuz TM-19 down 11-4-94

Launched but not in orbit

90 to 300 MILES

STS-66 U.S research	11-3-94	down 11-14-94

DATA: SAUNDERS KRAMER

Inoperative but still in orbit

90 to 300 MILES

Cosmos 2238
MSTI-2

21,750 to 22,370 MILES

Raduga 25

FORECAST

In the Wings...

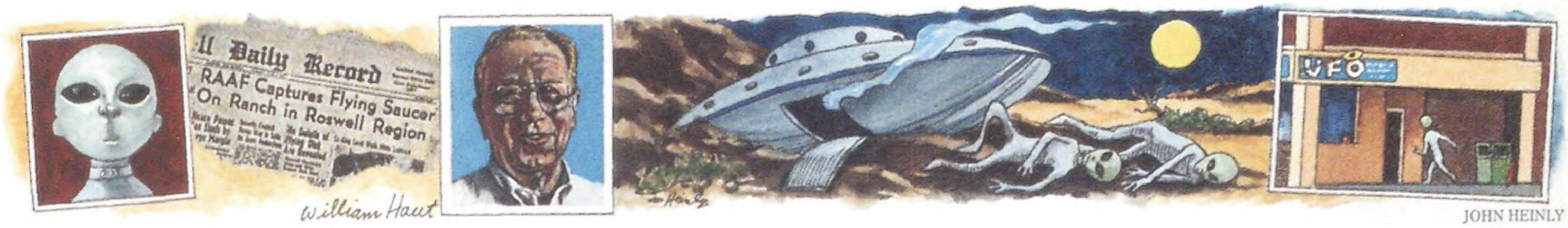
Under the Watchful Eyes. In the hierarchical society of an aircraft carrier, a pilot's career—and often his life—depends on the judgment of the one who scrutinizes his every approach and landing: the landing signal officer. **Plus:** A richly detailed, full-color cutaway poster of a modern aircraft carrier!

Tom Corbett, Space Cadet. He wasn't just another Buck Rogers, galloping through galaxies with no regard for science. By the time Tom Corbett came to television, space travel was beginning to look possible, and the Mercury program was just a decade away.

A New Map of the Milky Way. With a radio antenna that had been scheduled for demolition, a pair of astronomers traced every potential star-forming region in the galaxy and saved a historic observatory.

B-Chop!-52. How do you destroy the arsenal of B-52s that were to carry nuclear destruction to our cold war enemies? Rather spectacularly.

Mr. Goldin Goes to Washington. NASA chief Dan Goldin has been on the job for three years and through two administrations. He says he wants to reinvent NASA. Will he? Can he?



JOHN HEINLY

Shrine of the Flying Saucer

Walter Haut saw nothing. Well, he *says* he saw nothing, but in the convoluted case of the Roswell flying saucer, who can be sure? The story has been changed more often than a toddler's Huggies, and to the world's "ufologists," the results are just about as smelly.

According to recent books on the subject, during a fierce storm on or around the night of July 4, 1947, something exploded in the skies over Roswell, New Mexico. The next day, a rancher north of town found a metallic object wedged into a hill, as well as strange metal scraps scattered across a field. He brought a few of the scraps to the local sheriff, who advised him to contact the Roswell Army Air Field. Two base intelligence officers went to the field to investigate, and on July 8 airfield public relations officer Walter Haut issued a press release announcing that base personnel had discovered remnants of a "flying disk." But that afternoon, higher-ups in Texas issued a correction, stating that the men had only recovered the debris of a weather balloon.

Years later, the story took another turn. In the late 1970s Roswell intelligence officer Jesse Marcel told the world that what he'd discovered that day really was a UFO, fashioned of a thin, oddly resilient metal covered with hieroglyph-like markings. According to some versions of the story, Army investigators discovered not just a flying saucer but the bodies of aliens as well, and secretly autopsied them at the base hospital, then ferried them to Wright-Patterson Air Force Base in Ohio for further study (see "Aliens in the Basement," Aug./Sept. 1992).

Today, Haut, whose announcement started the whole affair, is a minor celebrity in UFO circles—"the man who wrote the press release." He is also the president and one of the founders of the two-year-old International UFO Museum and Research Center on Roswell's Main Street. And with all the visits and phone calls he receives from reporters and UFO enthusiasts, Haut is the museum's most prized exhibit. Visitors—flying saucer buffs and the mildly curious alike—grill him for details on the Roswell incident and describe their own close encounters with otherworldly machines and creatures. "This place is a magnet for just about everybody," says Haut. "You get to a point where you've got to separate the wheat from the chaff and everything in between. We keep the museum operating to bring forth good information, and to expose the public to information that's not tainted."

The International UFO Museum and Research Center, 400 N. Main St. (mail to: P.O. Box 2221, Roswell, NM 88202). Phone (505) 625-9495. Open daily, 1 to 5 p.m. Free admission.

So far, though, a visit to the museum shows that untainted information is scarce. The colorful displays include a wall-size artist's conception of the crash site (complete with expired space travelers) and photographs from "Roswell," a Showtime cable movie on the events of July 1947. A tableau shows one of the movie's alien mannequins lying on a gurney, with a physician mannequin posed next to it.

What the museum does not offer is solid evidence to confirm the Roswell UFO story. It serves up generic information on UFO sightings, descriptions of various kinds of close encounters, and photographs of metallic flying disks and cylinders, taken everywhere from Denmark to Bali. Newspaper and magazine articles tacked to the walls discuss the Roswell incident, as well as recent cattle mutilations in Colorado and Alabama and some mysterious lights that periodically appear in Lubbock, Texas.

The museum also has two video screening rooms. In one, visitors watch a 40-minute presentation on the Roswell crash. In the other, they pick from a menu of more than 30 titles, including "Crop Circles," "Hoagland's Mars," "UFO Secret," and a 1989 segment on Roswell from the TV series "Unsolved Mysteries."

For devotees of such topics, Roswell is something of a cross between Mecca and ground zero, the site of an almost mystical experience. So many visitors want to know about Roswell's flying saucer, in fact, that the city offers two museums devoted to the incident. The Outa Limits UFO Enigma Museum is located just outside the entrance to the former Army airfield. Its centerpiece is a diorama depicting the crash site, with alien dolls strewn beneath a metallic flying saucer.

UFO fans, of course, would rather see the real thing—if not the saucer, then at least the rugged arroyo where it allegedly crashed. One hot summer afternoon, a young Texas couple en route to Santa Fe dropped in to Haut's museum to ask for directions to the site. It lies on private land and is closed to the public, but the museum docents pointed out photos of the spot. While the young man asked questions, his partner videotaped the docent providing answers.

Last September, after an eight-month investigation, the Air Force concluded that the "saucer" remnants were most likely from a secret espionage balloon that had been undergoing testing. But Haut, like many of the visitors to his museum, isn't buying this latest twist to the story. "All they've done is send us another balloon, and that's been pretty well repudiated by all the investigators who have studied the crash," he says. And Haut points out that Jesse Marcel (now deceased) wasn't the only one to see the saucer. "Marcel's son, who's now a doctor, saw the same thing," Haut says. "Neither he nor his father had any reason to lie about it. I believe 100 percent of what they say."

Nonetheless, all he and his museum have to go on is other people's testimony. Haut himself says he never saw a thing. "I had nothing to do with it," he says. "I got a call from the base commander, and he basically dictated the release to me. I wish I *had* seen it."

—Damond Benningfield

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- *Standard four-wheel independent suspension*
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In the time it takes to read this headline,

Intrepid can do 10 million things.

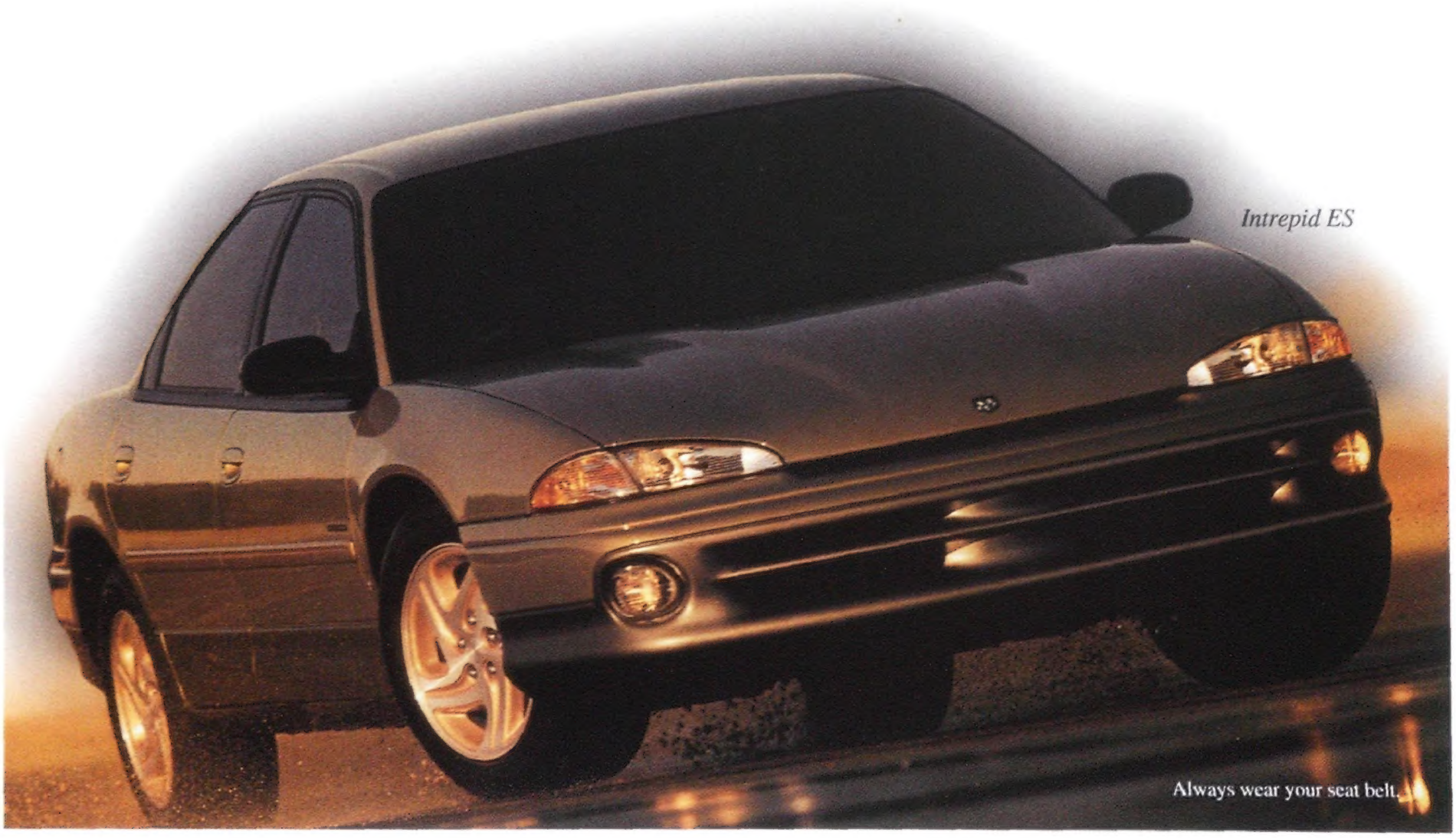
It hardly seems possible. But Dodge Intrepid has a network of as many as fifty-five data sensors and up to seven on-board computers that can process two million pieces of information per second.

It's clever enough to select shift points for optimum fuel economy. Turn off interior lights if a door is left ajar. And even maintain the inside temperature you want with available automatic temperature control.

It's amazing, when you stop and think about it. But then, Intrepid's computers work so quickly and efficiently...you probably never will.

Intrepid

The New Dodge
A Division of The Chrysler Corporation



FLYING EXCELLENCE: ROLEX AND THE EAGLES

Snap rolls, hammerheads, Cuban eights...these daring and intricate airborne maneuvers are just part of the Eagles Aerobatic Flight Team's vast repertoire. Flying wingtip-to-wingtip at speeds of 200 mph, often only six feet off the deck, the Eagles must perform with split-second timing. These gifted pilots wear the timepiece they can trust: The Rolex GMT-Master II Oyster Perpetual Date with an independent 24-hour hand and bezel. Available in stainless steel, 18kt. gold or a combination of steel and gold...It's your timepiece of choice when timing is critical.

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